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Research Report 1306

2 LEVEL II

HIGH MOBILITY DRIVER PERFORMANCE ANALYSIS

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The Combat Vehicle Technology Program's High Mobility Agility (HIMAG) Vehicle Chassis Tests, conducted in 1978 and 1979, provided an opportunity to explore the prediction of human performance requirements and the implications of high mobility tracked vehicle design for driver performance. Preliminary analysis and projections, based upon the vehicle concept during construction, were compared with data gathered during driver training and 20 km testing.

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Results supported the general hypothesis that cross-country driving on the higher horsepower per ton vehicles was significantly different from the same task on the M60A1 or M113. Course speeds, driver throttle use, driver errors and critical incidents showed a differential pattern on HIMAG trials. Human factors and human engineering design deficiencies in the driver compartment, some of which were predicted in preliminary analysis and training but were not resolved, probably limited HIMAG speed and maneuver.

Research Report 1306

HIGH MOBILITY DRIVER PERFORMANCE ANALYSIS

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FOREWORD

The accelerating acquisition of new Army equipment has increased the gap between equipment technology and human resources planning. The Combat Vehicle Technology Program, sponsored jointly by the US Army, the US Marine Corps, and the Defense Advanced Research Projects Agency, provided an opportunity to explore the implications for human performance in high performance weapons concepts. The research reported here examined methods for human performance analysis and, specifically, driver performance, in an experimental tracked vehicle, the High Mobility Agility (HIMAG) Vehicle.

This research was requested by and supported by the US Army Armor and Engineer Board and its Combat Vehicle Technology Division. It was conducted by the US Army Research Institute for the Behavioral and Social Sciences under Army Projects 2Q762722A764 in FY 1979 and 2Q162717A790 in FY 1980, with the participation and assistance of the US Army Armor and Engineer Board.

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JOSEPH ZEIDNER
Technical Director

HIGH MOBILITY DRIVER PERFORMANCE ANALYSIS

BRIEF

Purpose:

There is a need for better methods of estimation of personnel and training requirements in the early concept phase of weapon system development. There is also the possibility that higher mobility armor concepts now under consideration will impose new requirements for human resources development. This report on the High Mobility Agility (HIMAG) Vehicle driver was prepared in support of the Combat Vehicle Technology Program's HIMAG Chassis Tests, conducted by the US Army Armor Center and Fort Knox. It is directed toward the assessment of a method of crew performance estimation, operational sequence/task analysis, and the definition of special performance requirements of the high mobility tracked vehicle driver.

Procedure:

The research was conducted in three phases, which were coordinated with the HIMAG Chassis Tests. The first phase (1977) consisted of preliminary analysis of the HIMAG driver task, including concept development of operational sequences and derived subtask analyses during HIMAG vehicle construction. The second phase consisted of data collection during HIMAG driver training (1978) and the third phase consisted of data collection during the HIMAG 20 km tests (1978 and 1979), which included comparison trials with lower horsepower per ton (HPT) vehicle operations, the M60A1 tank and the M113 personnel carrier. Driver speeds attained in the 20 km test were analyzed in relation to driver errors in training and critical incidents (interruptions, losses of control, wrecks or machine failures) on the 20 km course. Audiotape and videotape records of 20 km test trials were analyzed for track commander (TC) messages, driver errors and mission interruptions. Extensive structured interviews recorded drivers' recollections of operational problems and ratings of vehicle operations and components.

Findings:

The preliminary analysis of driver operations was useful in identifying subtask sequences and subtasks presenting special problems in training and testing. Error inventory data collected during training provided insight into subtasks learned, high error rate items, patterns of performance improvements and omissions in training. Predictions of subtask difficulty were not confirmed by training or test data.

The training and the 20 km test data supported the general hypothesis that cross-country driving on the higher horsepower per ton (HPT) vehicles was significantly different from the same task on the M60A1 or M113. Higher HPT vehicles achieved higher course speeds as was expected with drivers using full throttle (accelerator depression) significantly less. Critical incidents were more frequent on HIMAG trials than on other vehicles. Most of these incidents involved driver errors, and of these, most involved attaining high speeds in relation to terrain conditions as reported by TCs. The HIMAG critical incidents attributed to machine component failures or engineering design deficiencies were not associated with higher speed driving. Human factors and engineering design deficiencies which were not resolved in earlier development probably limited speed and maneuver, especially on certain portions of the 20 km course.

Utilization of Findings:

Results will be included as part of the Combat Vehicle Technology Program report on the HIMAG tests. Results will also be used in preparation of driver training for higher performance tracked vehicle systems now in production. Concept estimation methods will be further evaluated and, possibly, included in a procedural guide for personnel subsystems development.

HIGH MOBILITY DRIVER PERFORMANCE ANALYSIS

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SECTION I

INTRODUCTION

During the concept and early development phases of the life cycle of a military weapon system there are many problems in the integration of human operators with the machine, in the development of human subsystems integration and crew performance requirements, in the definition of needed crew performances, and in the development of crew training (Kane, 1981; Fink and Carswell, 1980). These "bugs" in the human resources development have profound implications for longer range human resources planning -- for crew compartment and control-display design, for crew function allocations, for operational test data requirements, for long range training requirements, and for ultimate operational effectiveness. There is considerable incentive for resolution of these personnel subsystem problems early in the life cycle, because, in many instances, they can be resolved economically, provided they are addressed in an appropriate and timely manner prior to major expenditures for tooling and production.

The US Army has institutionalized human engineering, task analysis and new equipment training development. However, there is no coherent system for the development of personnel subsystem information and no available system for the timely integration of this information with machine subsystem development. The study reported here is part of a series of methodological studies of performance analysis and human resources integration directed toward methods and procedures for the timely development of human resources data and its integration into weapons systems development.

In the sixties Dunlap and Associates (Kurke, 1961) and the Matrix Corporation (Malone, Gloss, and Eberhard, 1967) along with the US Naval Personnel Research Activity (USNPRA) (Wilson, 1966, 1968) developed procedures for the derivation of system and personnel requirements using operational sequence analysis and combinations of task analysis and operational sequence analysis. A recent effort by ARI involved the application of operational sequence analysis to the analysis of turret manning requirements for the ground scout vehicle -- the Cavalry Fighting Vehicle (Bauer and Walkush, 1976). These experiences indicate that further refinement and synthesis of human performance analysis may result in significant cost savings in Army system training and testing development. The research work reported below was conducted cooperatively by ARI with the Armored Combat Vehicle Technology Program (CVTP) at the US Army Armor Center and Fort Knox. It should be noted that the selection of variables and, especially, the data collection, were constrained by field test limitations and unpredictable problems in experimental vehicle testing. ARI was requested to make human factors recommendations and to interpret personnel and training data (as were other agencies) but did not control the actual training, testing, variable selection, and data collection.

The Combat Vehicle Technology Program is unique in its effort to define the parameters and state of the art limitations in weapons concepts before the specification of the materiel requirements documents. The focus of CVTP attention has been on high-performance and higher technology armor concepts. For example, the High Mobility Agility (HIMAG) Vehicle Chassis test was primarily oriented toward machine concept variables in the HIMAG vehicle, especially power to weight ratios and suspension design in relation to different terrains and mission demands (US Army Armor and Engineer Board, 1977). However, a final assessment of the system capabilities would not be adequate without consideration of the crew's ability to learn to control the vehicle. The complete test program was planned to include fire control and tactical aspects, but the results reported here are limited to the HIMAG driver with some consideration for driver - track commander interactions.

OVERVIEW AND OBJECTIVES

Part of the US Army Research Institute's effort to integrate human resources data into the Army development cycle is devoted to the estimation of human performance requirements in concept weapons and determination of new human resources implications of advanced technology equipment.

The Combat Vehicle Technology Program, conducted by the US Army Armor Center at Ft Knox, KY, under the joint sponsorship of the Defense Advanced Research Projects Agency, the US Marine Corps and the US Army, provided an unique opportunity to explore the human requirements in concept high performance tracked vehicle weapons prior to the definition of system development requirements. The general hypothesis guiding the research was that high mobility tracked vehicle driving would be significantly different from current experience. Thus, the data reported here concern the high mobility tracked vehicle driver as exemplified in the High Mobility Agility (HIMAG) Vehicle Chassis Test performances.

The purpose of this research were:

(1) to obtain empirical data to validate the application of operational sequence analysis and associated task analyses (OS/TA) in concept or experimental weapons vehicles;

(2) to determine the human factors, personnel and training problems associated with the development of high-speed combat vehicles; and

(3) to provide support to the Combat Vehicle Technology Division in human performance aspects of the program.

Driver requirements data were developed during construction of the HIMAG vehicle. These were concept materials used in a preliminary analysis of driver operations. The preliminary performance analysis included development of operational sequences and analyses of driver tasks. These were actually completed before delivery of the HIMAG Chassis for the beginning of training at Fort Knox.

Empirical data and driver interviews were obtained during HIMAG drivers' training (1978) and during the 20 km test (1978-1979) which included comparative data on lower horsepower per ton (HPT) vehicle (M60A1 and M113) performances. These were parts of the HIMAG Chassis Test which involved a modified hull with automotive components, a driver, a track commander/controller, and (during training trials) an ARI observer. No weapons were mounted on the chassis and no gunner data were obtained in these tests.

The empirical data from training and testing were intended to be used to confirm, reject or correct results of the preliminary analysis, thus validating the OS/TA method, and additionally, to accumulate field trial information on human performance in high speed tracked vehicles. Though detailed driver data were collected during training trials, the corresponding human performance measures were omitted from the 20 km test trials, permitting no adequate comparisons between training and testing. Detailed analyses of the audiotape and videotape records of real time crew and vehicle performances during the 20 km test provided some additional insight into high mobility crew performances. However, since these results have not yet been adequately replicated, the "conclusions" to follow are largely expressed as hypotheses, to be considered for further reviews and testing.

SECTION II

PRELIMINARY ANALYSIS AND METHODS

Preliminary Analysis

During the construction of the HIMAG vehicle, Operational Sequence/Task Analyses (OS/TAs) were developed by ARI in consultation with engineers of the manufacturer, National Water Lift (NWL) Company, Ordnance Systems Division, Kalamazoo, Michigan. These were designed to chart the driver operational sequences in selected subtasks, to clarify the interactions (between driver and tank commander/test controller) and to identify potential problems and knowledge or skill requirements affecting operational success. OS/TAs were developed on the following driving subtasks: start, stop, pivot (or neutral steer) turn, rough terrain driving (vertical obstacle), rough terrain driving (ditch crossing), smooth surface-level, smooth surface-hill. (See Appendix A for OS/TAs.)

NWL had not previously prepared operational sequence analyses at the time these OS/TAs were developed, some details of driver operations were not precisely known, and some questions remained unanswered until the vehicle arrived for military driver training. However, the interchange between ARI and NWL was mutually beneficial in the preliminary detailing of driver operations. Further changes were made in the driver compartment and controls after this time. So the OS/TAs did not represent precisely the sequences required in the HIMAG as delivered (February 1978) as precisely as in the concept vehicle (September 1977).

Each step or combination of steps in each OS/TA was assigned a behavioral code adapted from USNPRA in which the first letter referred to the required behavior, the second letter to the means (mode or device), the third letter to display feedback and the fourth through seventh letters to GO or NO GO. The adapted code is defined in Table 1.

The analysis of the subtasks employed a set of predictions regarding operator performances made by the principal author and derived from two sources (1) examination of the OS/TAs, and (2) human factors observations on the prototype machine system (during its assembly at the plant). These Predictions Re Operator Performances are detailed in Appendix B. These were further analyzed by Subtask as to number and severity of problems and tentative remedial action (Table 2). A further derivation from this analysis was a ranking by the same author of predicted difficulty of subtasks for comparison with driver rangings at completion of training. (See Table 3.)

The subtasks were also ranked in terms of difficulty in learning and doing. This was accomplished by analysis of percent of subtask steps requiring cognitive functions, observing a time interval (waiting), communication, and GO or NO GO judgments. This content analysis yielded no differences in ranks as compared with Table 3.

TABLE 1

CODE FOR OPERATIONAL SEQUENCE/TASK STEPS

3 letters plus [if needed G or N (i.e., GO or NO GO)]

1st letter Function/Behavior		2d letter Means		3d letter Displayed or Not	
A	act	E	electronic	D	displayed
D	decide, estimate, judge	F	filed	N	not displayed
P	use, previously stored	I	intercom		
R	receive	M	visual-manual		
S	store	P	phone		
T	transmit	S	speech		
W	wait, observe time interval	T	touch, press		
		U	audio-visual-kinesthetic		
		V	visual check		

4th letter, etc.

G or N = GO or NO-GO
G = GO, Yes, OK
N = NO-GO, NO, abnormal

TABLE 2

SUBTASK PROBLEMS AND REMEDIES

Subtask	Number of Problems	Severity Ratings	Tentative Remedies
Start a	3	1	Control-display modification-retrofit.
b		1	Training emphasis.
c		3*	Training emphasis and, possibly, added instrumentation--retrofit.
Stop	1	1	Training emphasis.
Neutral steer (pivot) turn	1	2	Control-display redesign-retrofit and, possibly, operational sequence changes and training emphasis.
Rough terrain - vertical obstacle	1	3	Doctrine development and controls redesign-retrofit.
Rough terrain - ditch	1	3	Doctrine development and controls redesign-retrofit (similar or same as above.
Smooth surface - level	1	1	Training emphasis.
Smooth surface - hill	1	3	Machine components redesign - retrofit.

*3 = most severe.

TABLE 3

PREDICTED DIFFICULTY RANKINGS FOR COMPARISON WITH DRIVER RANKINGS DURING AND AFTER TRAINING

1	Starting
2.5	Rough terrain--vertical obstacle
2.5	Rough terrain--ditch crossing
4	Downhill driving
5	Pivot (neutral steer) turn
6	Smooth surface--level driving
7	Stopping

Instruments

Two driver data collection forms were prepared by ARI for performance evaluation during training and subsequent testing. These were as follows: (1) the Driver Performance Evaluation Form, a check list error inventory on the seven subtasks above, including a task performance rating on each subtask to be completed by an evaluator during training and test trials; and (2) a Vehicle Driver's Interview Form, a composite interview, made up by the task force interagency group to be administered following each relevant training/test trial. A third form, the HIMAG Crew Operations Questions, was a questionnaire developed by ARI to elicit the drivers' post-training evaluations of driving subtasks and operational problems. Two additional forms were developed for collection of critical incident data during (and after) the 20 km test. These were (1) a HIMAG Chassis Test Critical Incident form for completion by the TC as soon as possible following a critical incident; and (2) a Film Review Incident Report used in cross checking by the film reviewers after completion of the tests. These were prepared jointly by ARI and USAARENBD team members (Data forms appear in Appendix C.)

During the 20 km tests (but not during driver training) the HIMAG vehicle was instrumented with position location systems, tracking systems and telemetry instrumentation and sensors designed to permit monitoring of the machine and its controls. The instrumentation and telemetry systems are described in detail in Research Test of High Mobility/Agility Chassis by US Army Armor and Engineer Board, Ft Knox, KY (TRADOC Project No. 1-C1-7-000023-07).

The Test Drivers

Of the 14 military drivers who drove the HIMAG on the 20 km course, all had previously received the HIMAG (familiarity) training. There were wide differences in their HIMAG experience, ranging from the minimum training experience to more than 300 km. Table 4 shows the total distances driven by HIMAG drivers (including the 20 km test trials). The median enlisted grade of the drivers was E-5 and median age, 23. There were no significant differences in grade or age among M60A1, M113 and HIMAG 20 km drivers. There were differences in MOS with M60A1 drivers coming predominantly from MOS 19E (Armor Crewman), M113 drivers from MOS 11B (Infantryman), and HIMAG drivers from MOS 19E, F, G, J, and 11E (all Armor or Armor reconnaissance crewmen).

DRIVER TRAINING DATA, PROCEDURES AND ANALYSIS

Twenty-three military drivers received training under the direction of the NWL trainer from 9 March through 29 March 1978. Each received from three to seven driving trials (median = 4) with from 34 to 112 minutes total behind the steer-bar (median = 69). On each trial an ARI observer rode above and behind the driver so that he could score error items on the Vehicle Driver's Inventory Form and rate overall performance of each subtask on successive occurrences. One observer performed on all but a few of these trials (during which he was relieved by one of the authors). The training consisted largely of practice

TABLE 4

DRIVER EXPERIENCE

DRIVER	TRAINED-HIMAG	20 KM TEST VEHICLE				HIMAG TOTAL KM
		M60A1	M113	HIMAG 42.5 TON	HIMAG 33 TON	
1						0
2	Y			X		37.92
3		X				0
4	Y					23.84
5	Y			X		45.6
6		X				0
7 (C)						28.8
8	Y				X	153.76
9			X			0
10	Y			X		346.56
11	Y					6.72
12			X			0
13	Y					11.68
14		X				0
15			X			0
16	Y					29.28
17	Y					26.72
18	Y			X	X	76.48
19						56.0
20	Y					15.52
21			X			0
22	Y			X		112.64
23	Y				X	33.6
24 (C)						503.04
25	Y				X	47.04
26	Y				X	201.76
27			X			0
28		X				0
29	Y				X	23.04
30		X				0
31		X				0
32		X				0
33	Y					26.88
34		X				0
35			X			0
36 (C)			X			0
37	Y			X	X	98.88
38	Y			X		53.92
39 (C)				X	X	717.92
40	Y					28.0
41			X			0
42		X				0
43		X				0
44		X				0
45		X				0
46	Y				X	45.76
47	Y				X	38.24
48			X			0
49	Y					*

Y = received training
(C) = USAWES or NWL civilian driver
* = not recorded

driving exercises, with little intervention, correction or criticism by the NWL trainer who accompanied most runs. Each trial lasted from five minutes to sixty minutes in length; the mean trial duration was sixteen minutes.

Of the seven subtasks which were scored, some were not performed by all the drivers. Only 21 of the 23 driver trainees performed a pivot turn and most of these performed it only once. Only 11 of the 23 performed a vertical obstacle crossing and only eight trainees performed this subtask twice. The other five subtasks were each performed twice or more by all of the trainees.

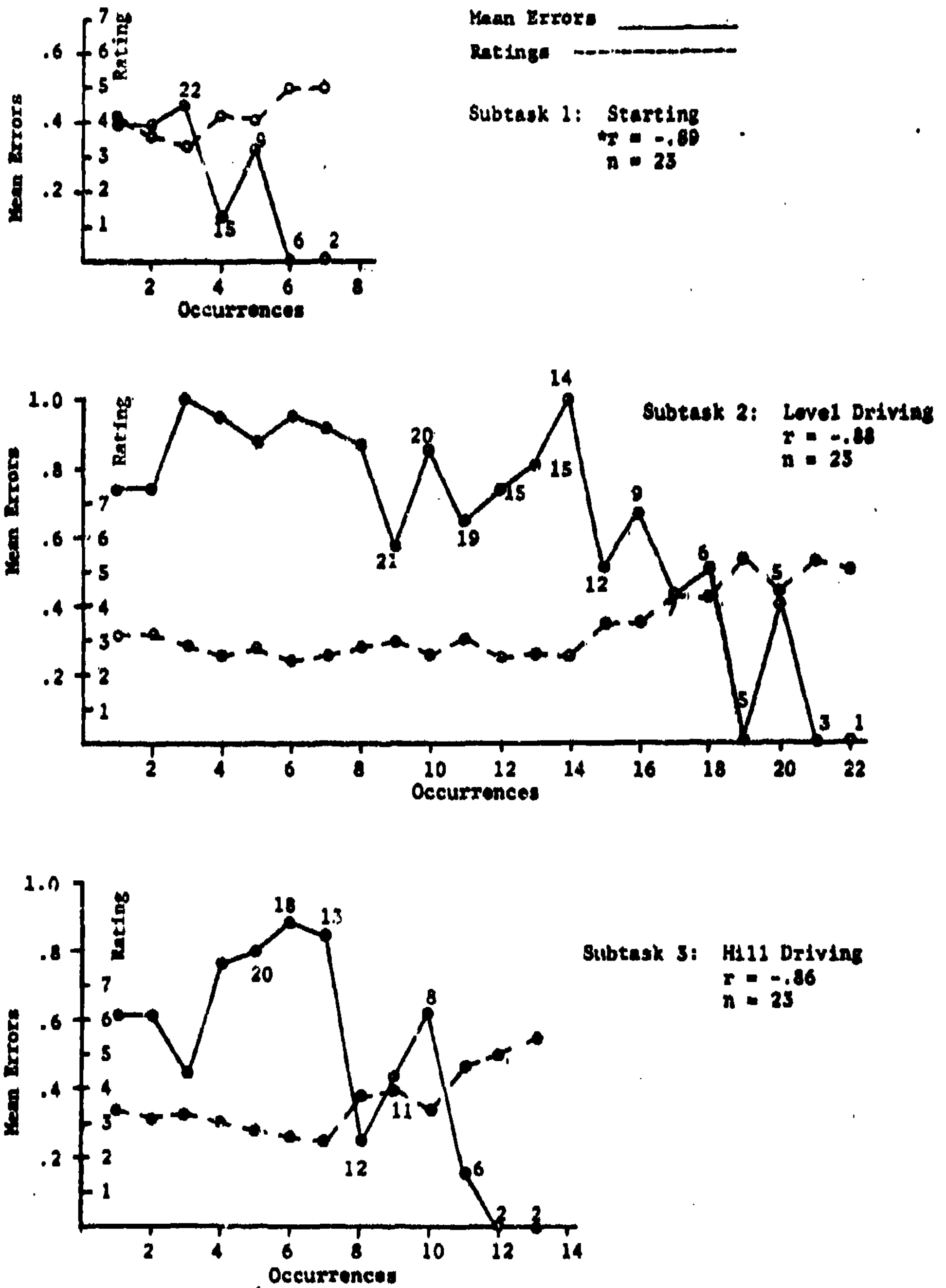
Mean errors among all drivers were compared on each successive occurrence of each subtask. This calculation provided a rough learning curve for each subtask showing diminishing error means with practice as expected. Figure 1 shows these as solid lines. As was expected, performance ratings improved with practice resulting in inverse correlations with error scores. Ratings on successive occurrences are shown as dashed lines in Figure 1. Pearson product-moment correlations were calculated on mean errors versus mean ratings at end of training (last two occurrences) on each subtask. Correlations between mean errors and mean performance ratings at end of training ranged from -0.93 to -0.73 (all $p < .001$).

Vertical obstacle crossing and pivot (neutral steer) turn -- two subtasks which received little attention in training -- showed the highest incidence of (mean) errors overall and the highest mean error item rates at end of training. Error rate on approach to the vertical obstacle was 50% (a common error was - approaches obliquely, not 90°), and error rate on stopping the neutral steer turn was 25% at the end of training (a common error was - stops by braking). This was not entirely consistent with the interview reports of driver trainees, who expressed little or no difficulty with these subtasks.

Ditch crossing and level driving, which were more practiced, also showed high error rates at end of training, after eight or more occurrences. "Bottoming out" or "pitching over hard" was the most frequent error item in ditch crossing (26%) and "looses control" was the most frequent error item in level driving (26%). Few trainees recalled their difficulty with these subtasks, less than 10% remembered ditch crossing as difficult, and less than 5% admitted they had done level driving poorly immediately after the driving trials.

Best learned subtasks (fewer errors persisting) were starting, stopping and (small) hill driving, and these were generally reported as easy at end of training.

The driver's post trial interviews revealed that most felt they could have run the preceding trial better. When queried about reasons, problems in (1) traction (slipping, sliding), (2) power train and transmission (lack of power), (3) visibility (muddy windshields, inadequate wipers), and (4) shock absorption and damping (bottoming out or bouncing over bumps) were most frequently mentioned. Each of the four problems were mentioned by 20% of the drivers. Also, three of the 23 drivers felt the angle of the accelerator pedal made it difficult to keep the foot from sliding off.

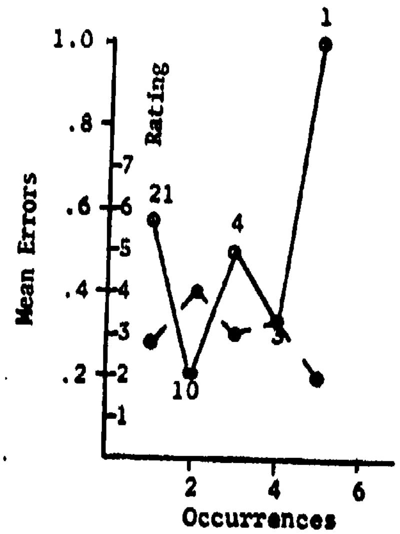


*Correlations are based on last two task occurrences, averaged, for each driver. All r significant at $p < .005$.

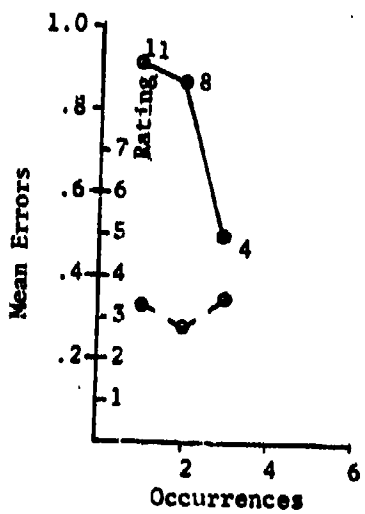
Figure 1. Mean Errors and Performance Ratings by Subtask Occurrence (any n less than 23 is shown beside point).

Mean Errors ————

Ratings - - - - - - -

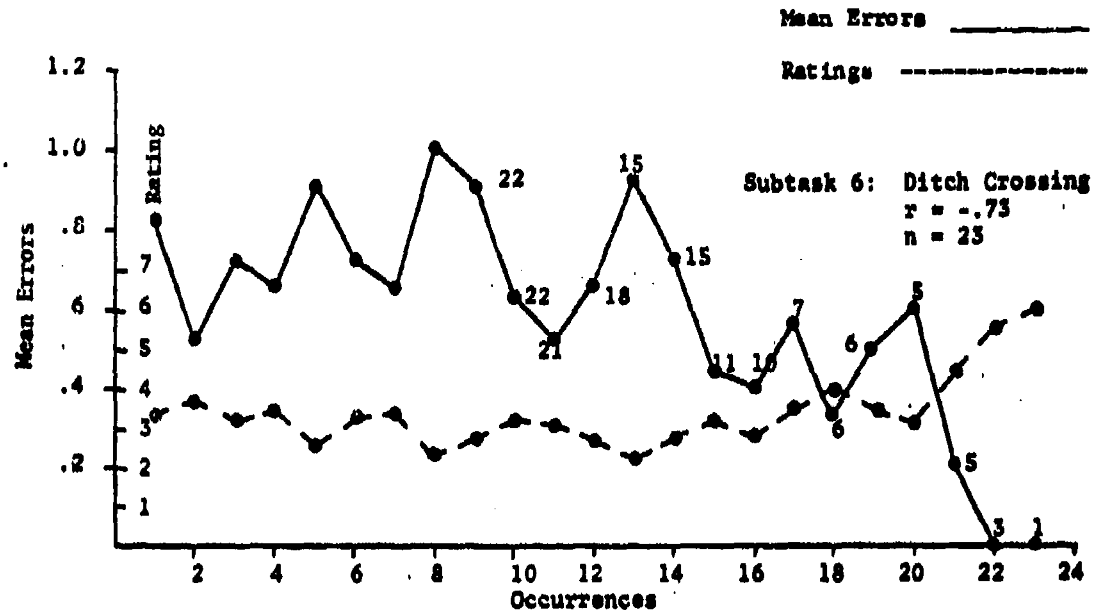


Subtask 4: Pivot Turn
r = -.76
n = 10



Subtask 5: Vertical Obstacle
r = -.93
n = 8

Figure 1. (continued)



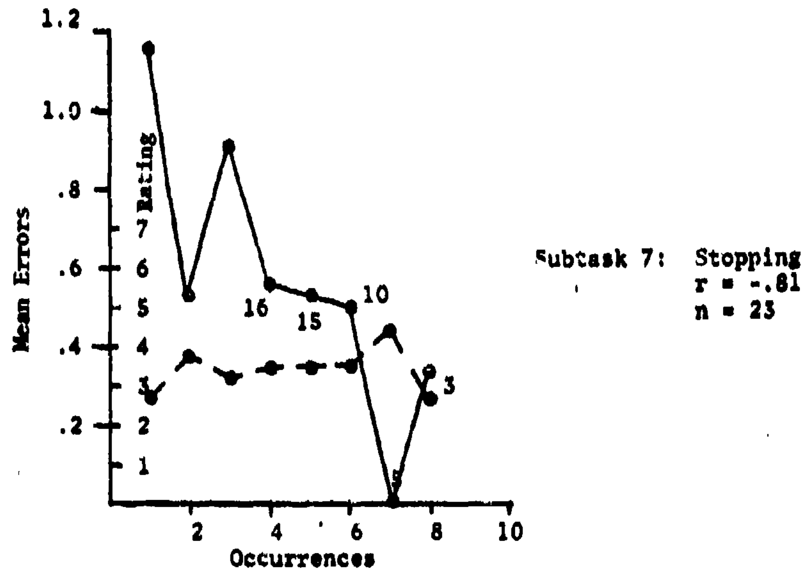


Figure 1. (continued)

In general, despite occasional reports of "bottoming out" or "bouncing," the HIMAG ride was described as smooth (69%) and relatively quiet (78%) by end of training. Trainees used expressions such as "good ride," "better than an M60," "sweet," "steady," "outstanding." Nevertheless, almost one-third (30%) of the drivers mentioned rough riding on rough terrain. All of these were on third or fourth trial runs by the trainee. Whether these poor ride experiences were associated with subsystem failures is not known. Additional trainee comments which are of less general interest, but more specific to human factors of the HIMAG itself, are in Appendix D.

After training was completed, the trainees were asked to rank order the difficulty of five subtasks (including rough terrain vertical obstacle and ditch crossing as one). The trainees ranking corresponded only in part to the predicted ranking of difficulty as indicated in Table 5. The inversions (disagreements) in ranking are represented by the line crossings (5). The Kendall tau, a statistic which emphasizes agreements and disagreements in ranking, was 0.33. This correlation was not significant at $p < .05$. This tau of 0.33 is a direct indication of the proportion of agreements in rank in excess of the proportion of disagreements in rank. Since the number of subtasks is small a correction for continuity was applied, resulting in a corrected tau = 0.27.

Starting, which was predicted to be most difficult, because of the complicated simultaneous hand-foot control and timing necessary, was found by the trainees to be least difficult. Only 5 of the 23 (22%) indicated operation of the brake pedal during starting as a problem and most of these marked it a minor problem. Six (26%) indicated some problem in starting, primarily in the simultaneous operation of brake pedal, accelerator pedal and starter button, which was as expected.

Reports by observers obtained after the close of training helped to explain the difference between the prediction from preliminary analysis and the drivers' reports. The starting task was actually only performed in part on most occasions by most drivers, as the engine was usually running hot from the previous run when the driver climbed aboard. Therefore, certain steps in the starting sequence were rarely actually performed by the trainee drivers.

Though stopping was predicted to be low ranking in difficulty (6th) and was so regarded by the trainees (5th), it elicited the largest number of critical comments on the questionnaire after training (from 13 of 23 or 57%). Some trainees regarded the problem as severe or major. The pressure required to push the brake pedal combined with the sensitivity of the power brake system resulted in some sudden stops. Trainees suggested that the functional relationship between the braking control (pedal) force and the braking response should be made more nearly linear. A sampling of some of the comments follows.

"Brakes were too hard to push therefore causing driver to push harder than what he is supposed to."

"The HIMAG is very sensitive in braking -- perhaps with time in using the brake one can become accustomed to the braking."

"Brakes very powerful, sensitive."

TABLE 5

PREDICTED VERSUS OBTAINED RANK OF DRIVER SUBTASKS
(N = 12 TRAINEES WHO COMPLETED ALL SUBTASKS BELOW)

Subtask	Predicted Rank	Obtained Rank
Starting	1	6
Rough terrain vertical obstacle or ditch	2	1
Downhill	3	2
Pivot turn	4	3
Level	5	4
Stopping	6	5

SUMMARY OF DRIVER TRAINING RESULTS

Twenty-three drivers received training for the HIMAG chassis tests. The training consisted of practice driving over rough terrain for short periods. It was largely familiarity training with little information on performance or correction by the NWL trainer. Seven subtasks were scored by the ARI observer as they occurred, but some were not performed by all drivers. Driving in reverse, long downhill driving, and road driving were not performed by most drivers. Less than half the drivers performed a pivot turn or a vertical obstacle crossing more than once. Overall performance ratings on the various subtasks did tend to rise with practice as error scores declined (inverse correlations were significant at $p < .001$). Error rates tended to persist at a high level (26% to 50%) in subtasks which were not extensively trained (e.g., pivot turn and vertical obstacle) and in certain other highly practiced subtsks (e.g., ditch crossing and level terrain driving).

Drivers tended to recall vehicle defects better than their own operator failures. When questioned after operations they most frequently mentioned problems in traction, transmission of power, visibility, and shock absorption or damping.

The HIMAC ride was generally described as good, smooth and quiet. Yet thirty percent of the drivers mentioned rough riding on rough terrain and there were some complaints about "bouncing."

Controls and displays were generally regarded as easy to use after the first trial, with three exceptions. (1) Brake pedal pressure and sensitivity were most criticized. The required hard push sometimes resulted in a rough sudden stop. (2) The track tension and height adjustment procedures were never actually learned, probably because the NWL trainer was uncertain as to doctrine or standard procedures. (3) Speedometer location forced a choice between reading or maintaining the view through the windshield; as a result, a number of drivers reported that they never read the speedometer.

The drivers' rank ordering of subtask difficulty corresponded only in part to the rank order predicted in the preliminary analysis. Starting, which was expected to be most difficult because of the complicated hand-foot control and timing necessary, was found by trainees to be least difficult. Stopping was predicted to be low in difficulty and was so regarded by trainees, but nevertheless this subtask elicited the largest number of critical comments on the questionnaire after training; the brake pedal force and sensitivity requirements were criticized.

Though certain subtasks, such as starting, stopping and small hill driving were well learned, some subtasks and part [illegible]ks were neglected in training. Most drivers felt they could have done considerably better, even at the end of training. Track tension and height adjustments were either never made by trainees or made only on specific command. Very few practiced reverse driving or road driving. Vertical obstacle crossing, ditch crossing, pivot turn and level terrain driving still showed high mean error rates at the end of training.

20 KM TEST DATA, PROCEDURES AND ANALYSIS

20 km test data were collected in real time by video cameras trained on the HIMAG windscreen view and on the driver position, and supplemented by tape recordings of the intercom messages. In addition, forms were prepared for recording, by the track commander (TC), of error scores and ratings on driver subtask performances (corresponding to training subtask data forms), but under the 20 km test circumstances the TC was unable to complete these in near real time as planned, so they were not used. Post-trial data were collected in a structured interview with the driver, conducted immediately after the trial by a trained data collector (noncommissioned officer). This structured interview employed the Vehicle Driver's Interview Form (VDIF). Additional post-trial data were obtained from the TC who was instructed to report any vehicle damage, personal injury, near accident (near-miss), accident or interruption (including instances in which the vehicle stopped, reversed direction or left the course) as Critical Incidents. Later review of the audiotape and the windscreen view videotape records showed that the TC reported critical incidents included only about one third of the total, so the critical incidents data file was significantly enlarged. See Appendix C for interview and data collection formats.

Of the twenty-three drivers who received familiarity training on the HIMAG only fourteen drove the HIMAG on the Ft Knox twenty km course one or more times. In addition, a civilian driver drove the HIMAG through the course six times. All of these HIMAG trials were conducted in August and September 1978. There were twenty two HIMAG trials altogether, including the six driven by the civilian driver. For comparison with lower horsepower per ton (HPT) ratios twenty-two M113 trials and twenty-six M60A1 trials were also conducted in August 1978 and September 1979. Table 6 shows the recorded trials, classified as unfamiliar (U) or familiar (F). A familiar trial was driven by a driver who had travelled over the course before and was thus familiar with the course. Drivers were routinely instructed to drive the course as fast as they could go without injuring anyone.

US Army Waterways Experimental Station (USAWES) technical experts classified the twenty km course into five main groups of terrain and traction characteristics as indicated in Table 7.

The wide ranging differences in HIMAG driver driving experience (see Table 4) showed no linear relationship with mean speeds achieved on the 20 km test.

Relative speed performances were averaged by terrain groups for each vehicle type with unfamiliar and familiar trials distinguished (see Table 8).

Trial speeds over terrain groups were correlated positively with HPT as expected. The pattern which emerged was consistent, showing larger positive correlations with course familiarity. However, this difference between U and F was not statistically significant (see Table 9).

TABLE 6

1978 AND 1979 TWENTY KM RECORDED TRIALS CLASSIFIED
AS UNFAMILIAR (U) OR FAMILIAR (F)

		M60A1	M113	HIMAG 42.5 ton	HIMAG 33 ton	Subtotals
1978	U	4	2	5	7	18
	F	5 (2)*	3 (1)	6 (4)	4 (2)	18
Subtotals		9	5	11	11	36
1979	U	8	8			16
	F	9 (1)	9 (1)			18
Subtotals		17	17			34

*Parenthesis contains number of trials by civilian drivers (included in the preceding number.

TABLE 7

GROUPS OF SIMILAR TERRAIN AND SURFACE CHARACTERISTICS
AS CLASSIFIED BY USAWES

Code	Name	Terrain Units (incl.)	Description Distance in km (% of course)
CG	Crushed Gravel	1-21, 101-115, 21-1	Crushed gravel, relatively smooth, level 6.96 (35.0)
DT	Dirt Trail	22-35, 116-124, 35-22	Dirt surface, rough, up and downhill, some gulch crossings 5.11 (25.7)
HH	Hog Hollow	36-45, 45-36	Dirt surface, sharp turns, a creek fording 1.83 (9.2)
PL	Pipe Line	46-79, 61-46	Dirt surface, very rough up and down hill, some troughs and gulch crossings 3.65 (18.4)
TT	Tank Trail	80-100	Dirt surface, some troughs and sloughs, deep gullies 2.33 (11.7)

Administrative interruptions were eliminated from the elapsed times on these segments.

TABLE 8

MEANS OF UNFAMILIAR (U) AND FAMILIAR (F) TRIAL SPEEDS OVER DIFFERENT TERRAIN GROUPS AND ARRANGED IN ORDER OF INCREASING HORSEPOWER PER TON (HPT). (Adapted from data analysis by USAWES.)

Terrain Gp	Mean speeds (military drivers) . . . mph							
HPT	M60A1 15.5		M113 21.9		HIMAG42.5 32.9		HIMAG33 45.5	
Code	U	F	U	F	U	F	U	F
CG	22.2	22.8	24.0	24.5	37.4	36.2	35.4	39.6
DT	18.2	19.7	21.2	21.2	27.4	32.8	29.9	35.2
HH	9.8	11.0	12.6	12.8	15.8	16.7	14.6	19.7
PL	10.0	11.4	13.0	13.9	18.5	20.1	19.4	23.6
TT	13.9	14.6	17.1	18.1	20.8	21.6	21.7	26.6
Total course means	15.1	16.4	18.1	18.8	25.0	26.0	25.0	30.0

TABLE 9

CORRELATIONS** BETWEEN MEAN SPEEDS AND HPT (MILITARY DRIVER TRIALS). COLUMNS NOT SIGNIFICANTLY DIFFERENT ($t < 1$; $p > 0.10$)
*CORRELATION SIGNIFICANTLY DIFFERENT FROM ZERO AT $p < 0.05$.

Terrain Gp Code	Correlations . . . speed with HPT U	F
CG	.867	.964*
DT	.977*	.953*
HH	.805	.996*
PL	.948	.989*
TT	.944	.996*

**Pearson product-moment correlations

A driver's throttle movements were recorded as evidence of his use of available power. Percent of total trial time at full throttle was compared across configurations. In general, drivers used less time at full throttle in the higher powered HIMAG configurations, but only the difference between the lighter HIMAG 33 and the M113 was significant [See Table 10 -- One way ANOVA: $F = 4.94$, $p < 0.01$; Newman-Keuls $q = 4.53$, $p < 0.05$ (Winer, 1971)].

At the close of training an error score had been selected from among alternative formulations as reasonably representative of training improvement. It consisted of the change in mean error counts from the first two trials to the last two trials, minus the mean final error count: $\bar{e} = \Delta\bar{e} - \bar{e}_2 = \bar{e}_1 - \bar{e}_2 - \bar{e}_2 = e_1 - 2e_2$. This made use of the earlier finding that changes in error scores were associated with the practice experience in training, and the assumption that a low final error score may be expected to indicate relative proficiency. However, no significant relationships were found between error scores in training and mean trial speeds, on the 20 km. Neither was there any significant relationship between error scores and frequency (per trial) of critical incidents on the 20 km course. Unfortunately, the TC was unable to collect the corresponding error data on the 20 km course, so these scores were not available.

Critical incidents included all occasions of unplanned interruptions in mobility or deviations from the course, and incidents of actual or potential damage to the vehicle or injury to personnel. Analysis revealed that critical incidents were distributed differently on the course for different vehicles. M60A1 critical incidents were distributed fairly evenly, but M113 and HIMAG incidents were concentrated in Pipeline and Hog Hollow, respectively.

While Table 11 conveys some information, it does not satisfy the minimum limitations for application of the chi square statistic. Therefore, the table was collapsed to increase the size of estimated expected frequencies to approximate the required minima and expected frequencies and adjusted residuals were calculated. Table 12 shows observed critical incident frequencies, estimated expected frequencies and adjusted residuals for the collapsed table. The clustering of M113 critical incidents on Pipeline and the clustering of HIMAG critical incidents in Hog Hollow suggests a difference between vehicles in control characteristics.

Most of the driving difficulties above were inferred from content analysis of real-time data (audio transcripts and film records) plus vehicle damage records, and were not reported in post-trial interviews of drivers or in TC reports.

Critical incidents also showed a differential distribution across vehicles on analysis of unfamiliar (U) and familiar (F) trials (see Table 13).

It appears that M60A1 and M113 critical incidents occurred more on unfamiliar (U) trials, whereas HIMAG critical incidents were scattered among both unfamiliar and familiar trials. However, Table 13 does not account for number of critical incidents as a function of opportunity, which is more obvious in Table 14. In this table each trial is treated as an extended opportunity for the

TABLE 10

PERCENT OF TOTAL TRIAL TIME DRIVER OPERATING FULL THROTTLE

HPT	$M60A1_{15.5}$ (All U)	$M113_{21.9}$ (2U; 2F)	$HIMAG_{32.9}$ (3U; 4F)	$HIMAG_{45.5}$ (6U; 3F)
TRIALS	70	65	75	46
	86	68	63	21
	36	70	46	25
	44	73	31	24
			65	6
			33	37
			70	46
				39
				67
$\bar{x}$	59	69	54.7	34.6

TABLE 11

RECORDED CRITICAL INCIDENTS BY TERRAIN GROUP AND VEHICLE

Terrain Gp Code HPT	M60A1 15.5	M113 21.9	HIMAG 32.9	HIMAG 45.5	Totals
CG	6	2	5	2	15
DT	3	0	1	3	7
HH	4	2	11	14	31
PL	5	14	3	0	22
TT	1	4	5	3	13
Totals	19	22	25	22	88

TABLE 12

COLLAPSED TABLE OF CRITICAL INCIDENTS, SHOWING OBSERVED FREQUENCIES, ESTIMATED EXPECTED FREQUENCIES AND ADJUSTED RESIDUALS (Haberman, S. J., 1978, pp 112-115) $\chi^2 = 35.13$; $p < 0.001$) *

Terrain Gp Code HPT	M60A1 15.5	M113 21.9	HIMAG 32.9	HIMAG 45.5	Totals
CG, DT, TT	10 7.56 1.29	6 8.75 -1.38	11 9.94 0.51	8 8.75 -0.38	35
HH	4 6.69 -1.37	2 7.75 -3.13	11 6.81 2.20	14 7.75 3.22	31
PL	5 4.75 0.15	14 5.50 4.83	3 6.25 -1.78	0 5.50 -3.12	22
Totals	19	22	25	22	88

*The use of X^2 here takes some liberty with the required independence assumption. Most, but not quite all, the incidents within and among cells were independent events, i.e., involving different drivers and different trials. The same caveat applies to the analysis of Table 14 following.

TABLE 13

TRIALS (ALL TRIALS INCLUDING CIVILIAN DRIVERS)
DURING WHICH CRITICAL INCIDENTS OCCURRED (OR DID NOT OCCUR)

	M60A1		M113		HIMAGs	
	U	F	U	F	U	F
Trials with critical incidents	7	1	6	2	9	10
Trials without critical incidents	5	13	4	10	1	2
	12	14	10	12	10	12

TABLE 14

CRITICAL INCIDENTS ON UNFAMILIAR AND FAMILIAR TRIALS AS A FUNCTION OF TRIAL RUNS
$\chi^2 = 19.32$ (df = 1); $p < 0.001$

	M60A1 and M113			HIMAGs		
	U	F	Total	U	F	Total
Number of:						
Critical incidents (o_i) observed	31	10		14	33	
(Σo_i)			41			47
Critical incidents (e_i) expected	18.8	22.2		21.4	25.6	
Trial runs (n_i)	22	26		10	12	
(Σn_i)			48			22

$$e_i = \frac{n_i}{\Sigma n_i} \cdot \Sigma o_i$$

TABLE 15

CRITICAL INCIDENTS ASSOCIATED WITH PRESUMED PRIME CAUSES, DRIVER ERROR, TEST CONTROLLER ERROR, VEHICLE (COMPONENT) FAILURE OR VERY DANGEROUS TERRAIN

		M60A1		M113		HIMAG 45 tons		HIMAG 33 tons	
	REPORTED SPEED	HI	LO or no record	HI	LO or no record	HI	LO or no record	HI	LO or no record
CREW	DRIVER	4	14	6	15	9	1	11	3
	TC	0	1	0	0	0	1	0	1
OTHER	VEHICLE	0	0	1	0	4	9	6	0
	TERRAIN	0	0	0	0	0	1	0	1
	TOTALS	4	15	7	15	13	12	17	5

TABLE 16

MEAN INCIDENCE (PER TRIAL) OF TC INTERCOM STATEMENTS
CLASSIFIED BY CONTENT ACROSS CONFIGURATIONS

Config.	Trial n	Commands . . . . +s	-s	ks	Other	Inf	?	Uncl	Mean Total Messages
M60A1	4	2.2	3.2	1.0	8.2	15.8	9.2	6.5	46.1
M113	4	1.8	3.2	0.5	4.8	10.5	0.5	0.8	22.1
HIMAG 42.5	7	3.9	7.7	0.3	6.6	11.7	4.0	1.7	35.9
HIMAG 33	9	1.9	4.1	0.3	4.0	11.7	3.4	1.6	27.0
Mean overall		2.5	4.9	5.6	12.2	4.1	2.3	13.4	32.0

Legend: + s = Increase speed
- s = Slow down.
ks = Maintain speed or keep this speed.
Other = Miscellaneous commands not implying speed control.
Inf = Providing information about the course.
? = Question addressed to driver.
Uncl = Unclassified remarks, exclamations, etc.

occurrence of critical incidents. This also provides a means of calculating expected frequencies (e_i) on an assumption of independent likelihood within classes of vehicles.

Critical incidents were also associated with high or excessive speed (as reported by the test controller or extracted from the audiotape records) in many instances, but especially on HIMAG runs (see Table 15).

Further examination of the attributed causes of the critical incidents indicated whether driver, test controller [who was also track commander (TC)], vehicle components, or terrain difficulty were considered to be prime causes. Attributed causes were assigned by one of the authors on the basis of review of audiotapes, TC reports, film reviewers' judgments and recorded machine component failures. Most critical incidents were attributed to driver errors in all configurations, but the experimental vehicle (HIMAG) showed more component failures, and driver-caused critical incidents were still predominantly associated with high speed performances.

TC intercom statements were analyzed in an effort to determine whether there were significant differences in TC behaviors on the different configurations -- behaviors which may have influenced results. Civilian driver trials were excluded from content analysis of TC intercom messages. TC statements were classified as commands to increase speed, decrease speed, maintain speed, or other commands. Three additional categories were provision of information, questions addressed to the driver, and "unclassified." Table 16 shows the distribution of TC messages by content and configuration.

For the purpose of statistical analysis, Table 16 was consolidated into a 3 x 2 table (not given here) of speed commands, other commands, and miscellaneous messages, versus HIMAG configurations and other vehicles. Analysis (chi square) indicated no significant differences among the classes of messages across the two configurations.

SUMMARY OF 20 KM TEST RESULTS

The failure to find positive relationships between training measures and 20 km test performance measures was disconcerting, but should have been expected in view of data collection decisions during testing.

Error scores and ratings of subtasks on the 20 km course were designed to correspond to the training measures, but were not actually obtained during the test trials. The TCs assigned the task found that they were unable to complete the written forms in real time because of the high acceleration environment. In terms of the demands on both driver and TC, the very challenging 20 km test was quite different from training. No such emphasis upon speed and maneuver over such rough terrain was experienced in training. Thus, there were differences between measurement methods and between task characteristics obscuring any relationship which may have been present.

TC reports of critical incidents in the 20 km test were also incomplete, presumably because of the rush of events upon the TC. TCs generally reported these very shortly after completion of the trials rather than during the runs. However, these critical incidents were exhaustively cross-checked against audio- and video-tape records, post trial interviews, and vehicle damage records, so the resulting file was eventually completed and validated.

The 20 km test data did support the hypothesis that cross-country driving on the higher HPT tracked vehicles was significantly different from the same task on lower HPT vehicles (M60A1 or M113). Trial speeds were correlated positively with HPT. Drivers achieved these higher speeds using less time at full throttle, especially on the highest HPT vehicle. Critical incidents were associated with these higher speeds, especially on HIMAG runs. Critical incidents were not only twice as frequent on HIMAG runs, but occurred more frequently on familiar runs, whereas M60A1 and M113 critical incidents occurred less frequently and predominantly on unfamiliar trials. Thus, critical incidents, especially those associated with speed, occurred more frequently as the driver exploited power for speed over familiar terrain.

The divergent frequencies of critical incidents on different course segments for M60A1, M113 and HIMAG trials were not likely due to chance. The relatively large residuals in several cells indicate that the differences involved more than one configuration and more than one terrain group (see Table 12). Whereas, the hypothesis -- that cross-country driving on the higher HPT vehicles is significantly different from most tracked vehicle driving experience -- can be generalized to vehicles in the HIMAG HPT and speed ranges, the critical incidents data for different terrain groups may be more specific to human factors and control characteristics of the test vehicles. Nevertheless, the data suggest some engineering design and human factors requirements of similar high mobility-high maneuver vehicles.

Most of the HIMAG critical incidents (55%, for both configurations) occurred in Hog Hollow (HH) which made up only 9% of the course. This section is characterized by sharp turns, dirt, and, often, mud surfaces. Excess speed driving (39%), slippery mud surfaces (39%) and some brake failures (22%) were associated with these incidents. Vision limitation by mud on the windshield was reported after two thirds (68%) of the HIMAG trials. The obscuration of peripheral vision may have severely handicapped HIMAG drivers on these sharp turns and slippery surfaces at the speeds attainable (14.6 to 19.7 mph mean speeds in HH). Such vision limitations were never reported by M113 drivers. However, the M113 drivers experienced most of their critical incidents (64%) along the Pipeline (18% of the course including extremely rough vertical accelerations). Here the superior ride of the HIMAG may have given an advantage. The M113 incidents were attributed entirely to driver control failure (100%), often combined with mud surfaces (64%).

While most of the HIMAG critical incidents were associated with high speed and driver error, there were, apparently, also engineering design features which contributed to loss of control or machine failures (see Appendix D). The critical incidents in which vehicle component failure was presumed to be the prime cause were not especially associated with high speed. For example, in wet and muddy terrain, the visibility limitations imposed on the HIMAG driver by the inadequate windshield washer system severely hampered his performance. Under such conditions the number of critical incidents was high.

SECTION III

DISCUSSION AND CONCLUSIONS

The operational sequence/task analysis (OS/TA) of driver subtasks proved useful in two ways. It provided the basic information for construction of the subtask error inventory, and gave both the user and manufacturer some insights into human factors problems in driver training and operations and in HIMAG driver station design. In another way the OS/TA was not as accurate as expected. The subtasks were rank ordered for predicted difficulty (in training or execution), but this did not correspond to the order of difficulty reported after training by the trainees. The disagreement was entirely attributable to the inversion of one subtask, starting, which was predicted to be most difficult and found by trainees to be least difficult. This disagreement may be explained post hoc by the observation (during training) that most drivers did not go through the entire starting sequence on each trial, since they often found the engine running hot from the previous trial. It can be concluded that analysis of subtasks in forms of problem/severity extracted reasonable predictions of subtask difficulty from operational sequence/task analysis.

Identification of subtasks and recording of subtask occurrence during training exercises appears to have a value separate from the analysis and evaluation above. For example, it is important to know which subtasks have been performed a given minimum number of times during training and by what proportion of the trainees. Some trainees were found to have no experience in certain subtasks, and certain other subtasks or part tasks were simply not offered in training.

The driver performance error inventories data provided not only detailed knowledge of errors and error rates but also revealed training and learning patterns. The driver error inventories showed more sensitivity than the performance ratings, that is smaller variances and significant ($t = 2.39$, $p < .05$) change from starting to ending mean scores. Changes in means of performance error inventories also provided insight into the parts of subtasks showing continued high error rates (in subtask error item analysis). Furthermore, certain training deficiencies were apparent from the analysis of repeated trials, e.g., some trainees were found to have had little or no experience in the performance of certain driving subtasks. On subtasks which were practiced repeatedly, there was evidence of performance improvement over trials. Variances in error performance among drivers were also smaller at the end of training than at the beginning, as would be expected from training experience. The observers' performance ratings were inversely correlated with error scores as expected (all subtasks $p \leq .005$), but the ratings did not show significant performance improvement with practice.

The disagreement between predicted subtask difficulty rankings and subtask difficulties reported by drivers persisted after the 20 km tests. Drivers' reports of subtask difficulty showed no correspondence to the preliminary (to training) predictions or to their own erarlier (post-training) observations.

Some consistencies are worth noting. Stopping, which was regarded as relatively easy by most drivers, was admittedly poorly done by two drivers and elicited the most related complaints after the test, as it had after training (i.e., complaints about braking action). Complaints about speedometer location persisted after the 20 km test and after training. Neutral steer turn and ditch crossing, which showed high mean error rates at the end of training (neutral steer turn was practiced very little) also showed a high number of related complaints after the 20 km test. Starting, which was predicted to be difficult, and probably not correctly practiced by the driver trainees, elicited complaints from several drivers after the first 20 km trial of the day. (In the start-up trial they had to perform the whole procedure.) They said they "needed more training."

Though driver errors on the 20 km course appeared to be closely related to many critical incidents (excluding certain machine component failures), the earlier training measures and training experiences were not designed to elicit critical incidents and high speed performance, two factors which emerged as important in the 20 km trials. Analysis of error patterns in training showed no apparent relationship with critical incidents or attained speeds on the 20 km course. The training, which consisted essentially of familiarity with vehicle operations at moderate speeds in a mildly challenging environment, was not directed toward the 20 km performance demand -- relatively high speed driving over very rough, extremely challenging terrain.

The training and 20 km test data did support the general hypothesis that cross-country driving on the higher HPT vehicles was different from the same task on the M60A1 or M113. Twenty (20) km trial speeds were correlated positively with HPT. Higher HPT systems achieved higher trial speeds with drivers using full throttle significantly less on the highest HPT vehicle. Critical incidents (temporary losses of control, near-misses or wrecks) were much more frequent (2x) on the HIMAG trials than on other vehicles. Most of these were associated with driver errors and, of these, most involved relatively high speeds in relation to terrain conditions as reported by TCs. HIMAG critical incidents occurred predominantly on familiar terrain, whereas M60A1 and M113 critical incidents occurred mainly on unfamiliar terrain. Some HIMAG critical incidents were obviously associated with vehicle component failures, and others were associated with conditions and human factors limitations such that engineering design deficiencies were considered as probable causes. Human factors and engineering design deficiencies which were not resolved in earlier development probably limited speed and maneuver, especially on certain portions of the 20 km course. There was some effort to discriminate generic (high mobility tracked vehicle) human factors problems from those human factors problems specific to this unique experimental vehicle. However, this discrimination remains a matter of the authors' judgment. The judgment is based on multiple indicators of probable causes and an experienced speculation about components and characteristics likely to be found in the broad class of high mobility tracked vehicles (see Appendix D for human factors problems regarded as specific to the HIMAG).

There is a more general problem observed in weapon system performance measurements. Systems measures (e.g., mean course speeds, number of critical incidents) are expected to reflect operator or crew performances, but are known to be influenced heavily by machine variables. Without very special instrumentation for the purpose, it is difficult to obtain clean measures indicative of crew performance distinct from such system measures. Further research must be addressed to discriminating the operator or crew indices in the context of field tests of systems.

The following conclusions and hypotheses summarize much of the data assembled here and can be generalized to and tested against experience with other high mobility tracked vehicles.

1. Operational sequence/task analysis (OS/TA) of concept operations can be used to identify task sequences and predict special task performance and training requirements or problems. (Conclusion)

2. Error inventories derived from the OS/TA can be used to record training data performance improvement. (Hypothesis)

3. High mobility tracked vehicle driver training and operational requirements are significantly different from driver requirements in currently fielded tracked vehicles. (Conclusion)

4. High mobility driver training and assessment must include the more challenging operations and measures derived from mission (test) performance requirements if the training is to be criterion-related. (Conclusion)

5. Tracked vehicle crews, when so directed, will exploit horsepower per ton (HPT) for speed and get higher speeds on familiar terrain. (Hypothesis)

6. Critical incidents associated with driver error will mostly also be associated with higher speed performances on the higher mobility vehicles. (Hypothesis)

7. High speed and maneuver over challenging terrain may be limited by human factors and engineering design deficiencies if these problems are not resolved in earlier design development (e.g., for field of view obscuration, driver's display layout and controls problems, see Appendix D). (Conclusion)

IMPLEMENTATION RECOMMENDATIONS

Performance and training requirements of the high mobility driver will be important in Army Staff decisions on characteristics of the high agility light weight Armor concepts to be developed for the 1990s. This report will comprise a part of the US Army Armor and Engineer Board Combat Vehicle Technology Division report on the HIMAG Chassis Tests. It will also be used separately for its information on high mobility driver performances in state of the art or high technology weapons concepts and weapon systems.

Further research on the high mobility track driver must include more data on crew interactions than could feasibly be captured in the HIMAG Chassis Tests, including more data on tactical driving requirements. Measures for mission performance assessment must be selected for relevance and applicability to both training and testing. System performance measures must be defined operationally to reference highly probable crew performance parameters.

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APPENDIX A

OPERATIONAL SEQUENCE/TASK ANALYSIS OF HIMAG DRIVER TASK

UNIT: HIMAC Crew
TASK: Drive
SUBTASK: Start

No.	Inter-related Operation	Step	Driver Action	Step	TC Action	Feedback (& Fault info) & Correction	(Time) Cumula-tive	Potential Problems	Knowledge/Skill Requirements	Notes
1				DFS G or N (PFS & EFS)	Confirm completion of BEFORE OPERATION CHECKS	If N, complete CHECKS.	(20) 20			
2		AIN	Plug-in helmet intercom				(05) 25			
3		AMN	Fasten SAFETY BELTS				(25) 50	Requires difficult manual joining of five parts against some tension with two hands.		
4		AMN	Adjust seat fore-to-aft, vertically, and seat back tilt				(15) 65			Left hand, rear of post (fore-to-aft). Left hands forward of post (vertical). Left hand, rear (seatback tilt).
5		AIN	Adjust SAFETY BELTS				(10) 75			
6		DMD G or N (BMD)	Check hand BRAKE full on (PARK)			If N, pull brake lever ON (to insure no inadvertent movement due to malfunction.	(02) 77	HEL advises this insure against unanticipated electrical anomaly causing movement.		
7		DMD G or N (BMD)	Check GEAR in N			If N, move gear to N (neutral).	(01) 78			Interlock prevents start in other gear positions.
8		DMD G or N (DMD)	Press-to-test warning lights			If N, check bulbs	(02) 80			Can we do this without MASTER BATTERY switch ON?
9		DMD G or N (AMD)	Check STEER BAR (S-BAR) center position PIN in lock position			If N, put S-BAR in center position and drop PIN into lock position.	(02) 82	Vehicle will pivot turn on starting if S-BAR not centered, S-BAR center position PIN will insure against accidental turn.		Is there NO indication of center position except for pin fit?

UNIT: HIMAC Crew
TASK: Drive
SUBTASK: Start

No.	Inter-related Operation	Step	Driver Action	Step	TC Action	Feedback (& Fault Info) & Correction	(Time) Cumulative	Potential Problems	Knowledge/Skill Requirements	Notes
10		DMD C or N (RMD)	Check fuel pump ON			Normally left ON while parked. Guard will fall down over switch in ON position only. If N, raise guard and switch ON.	(02) 84			
11		ATD	Press (left foot) on foot brake				(02) 86		Driver must understand that left foot is used on brake only during start up. Other operations employ right foot on BRAKE, or alternately, on ACCEL as in car driving	Is there a way to do this without using left foot on brake?
12		ATD (WTD)	Switch MASTER BATTERY switch ON			MASTER BATTERY light and ENGINE START MODE light come ON. As fuel pump and engine oil prime pump come on (electric motors sound) MALFUNCTION warning light will come ON and ENGINE LOW OIL PRESS and TRANS LOW OIL PRESS lights come ON. Engine oil prime pump will run ≤ 75 sec till oil pressure is in satisfactory range.	(03) 89			ENGINE START MODE light is on suspension console.

UNIT: HIMAG Crew
TASK: Drive
SUBTASK: Start

No	Inter-related Operation	Step	Driver Action	Step	TC Action	Feedback (& Fault Info) & Correction	(Time) Cumula-tive	Potential Problems	Knowledge/Skill Requirements	Notes
13		DVD G or M (EVD)	Check GENERATOR gauge			Yellow range G, battery voltage check. If Y, battery may require recharging.	(01) 90			
14		DVD G or M (EVD)	Check OIL pressure gauge			Green range G, and LOW OIL PRESS lights go OFF.	(01) 160 (Include wait 75 sec as above.)	Start prior to G may damage engine. (What parts?)		Do both ENGINE LOW OIL PRESS and TRANS LOW OIL PRESS lights go OFF?
15		ATD (DVD) (WUD)	Press STARTER button and HOLD ≤ 30 sec (during 16, 17, and 18)			If engine does not start in ≤ 30 sec, wait for cool down, about 2 min, and then repeat 15, 16, 17 and 18.	(01) 165		Considerable coordination and concentration will be required to execute this sequence involving both feet and both hands simultaneously (see 11, 15, 16, 17, 18, 19 and 20) while estimating time on two concurrent events.	
16		ATM (DRM) (WTM)	While holding STARTER button switch MANIFOLD HEAT on and HOLD for 0.5 to 2.0 sec				(05) 166	If STARTER button is pressed without MANIFOLD HEAT, engine may not start.		MANIFOLD HEAT is helpful, in starting even in moderate to warm weather.
17		ATD G or (DUD)	Slowly depress ACCEL pedal until engine starts			When engine starts noise is audible and RPM indicator rises. ENGINE RUN light comes ON and ENGINE START MODE light goes OFF.	(10) 176		TELEDYNE instructions leave operator uncertain whether there may be damage or special problems if STARTER is repeatedly pressed without waiting 2 min each time.	Both ENGINE RUN light and ENGINE START MODE light are on hydraulic condition indicator suspension console

UNIT: HIMAG Crew
TASK: Drive
SUBTASK: Start

No	Inter-related Operation	Step	Driver Action	Step	TC Action	Feedback (& Fault Info) & Correction	(Time) Cumulative	Potential Problems	Knowledge/Skill Requirements	Notes
18		ATN (DTN) (WUD G or N)	If engine has not started repeat switch MANIFOLD HEAT on and HOLD for 0.5 to 2.0 sec until engine fires smoothly			Engine running smoothly.	(05) 181			HAND (park) BRAKE is still ON.
19		AID	Release FOOT BRAKE				(01) 182			
20		ATD	Release ACCEL fully			Engine will fall into low idle (~ 1200 RPM).	(03) 185	ACCEL should not be released before engine is running smoothly (to avoid dying).		Driver may learn to discriminate low idle from auditory cues only.
21		DVD G or (RVD)	Check GENERATOR gauge			Must be green for G, if in high red generator is overcharging. If in yellow or low red generator is under charging. If N, maintenance is needed.				
22		WFN (DFN)	Wait 5 to 8 min for engine warm-up (before releasing hand brake). May proceed with 23-31 while waiting			Engine temp gauge needle will rise toward middle of green zone.	(360) includes 23-32 below	Temp numerals not visible. Driver must learn to wait minimum of 5 mins and estimate desired needle position as needle rises from low green to middle green.		(Experimental) instrumentation checks can be done during this warmup period.
23		DND G or N (TIN & RID)	Check intercoms							
24		TTN	Requests assistance with engine compartment checks	RID	TC will probably assist driver					

UNIT: HIMAG Crew
TASK: Drive
SUBTASK: Start

No.	Inter-related Operation	Step	Driver Action	Step	TC Action	Feedback (& Fault Info) & Correction	(Time) Cumulative	Potential Problems	Knowledge/Skill Requirements	Notes
25	*AMD G or N (AMD) Recheck engine oil level.					If S (not in SAFE TO RUN level) add oil.				*Steps 24, 25, and 26 must be done by a person other than driver—from top deck over engine. Engine compartment top deck must be raised to RESET.
26	*AMD G or N (AMD) Check induction air pop-up indicators.					Red is N; green is G. If N, air pop-up indicators can be rechecked by pressing RESET and observing for return to G or N.				
27	DIS G or N (AID) Check (feel) for air-flow out of scavenger blower ports (one on each side of chassis)					If N, maintenance is needed.		Will running in dirty (dust, sand) situation filter clogs with coarse particles if scavenger blowers not operating?		
28		DVD G or N (EYB)	Check TRANS oil pressure and ENGINE oil pressure green			If either N (not in green) and not corrected by oil addition (Step 24) maintenance is required.	(02)			

UNIT: HIMAG Crew
TASK: Drive
SUBTASK: Start

No	Inter-related Operation	Step	Driver Action	Step	TC Action	Feedback (& Fault Info) & Correction	(Time) Cumula-tive	Potential Problems	Knowledge/Skill Requirements	Notes
29		DVD G or N (RVD)	Check track tension gauge for correct level			Correct level TBD If N, set to correct level for terrain and operations anticipated.	(02)	How does driver know the correct tension level and how does he know that system is in this range for a certain broad variety of terrain? Are there markings on tension gauge?	Driver must develop judgment on relationships among speeds, operations and terrain types, for correct track settings.	Different settings will be correct for different types of terrain and operations (e.g., rough terrain and/or vertical obstacles will probably require higher track tension than smooth surface travel).
30		DVD G or N (RVD)	Check hydraulic system pressure gauge			If N, maintenance is required.	(01)		What if E? What is N?	
31		[illegible] (AMN)	Adjust (Chassis) height and trim to desired mode and lock Levers to desired friction				(10)	There is no display or gauge except the three gross markings, min, static, max, beside the three levers. How can the driver know what height or trim posture the system has assumed as a result of his adjustments?	What height and trim adjustment settings are desirable? Which are N? Is this a G or N?	(Levers on driver's left side.) STATIC is an intermediate height - horizontal position (on level).
32		ATD	PRESS and HOLD FOOT BRAKE till Step 36				(01)			
33		ATD	Release HAND BRAKE				(02) Not before 585	Must not be released before elapse of 5 min from Step 22.		
34		DVD G or N (RVD)	Check anticipated path of travel for hazards or obstacles			If N, wait for CLEARANCE.	(03)			

UNIT: HIMAG Crew
TASK: Drive
SUBTASK: Start

No	Inter-related Operation	Step	Driver action	Step	TC Action	Feedback (& Fault Info) & Correction	(Time) Cumulative	Potential Problems	Knowledge/Skill Requirements	Notes
35		ATD	Remove S-BAR center position PIN and drop				(02)			PIN will hang on chain when not in use.
36		AMD (IMD)	Place GEAR shift lever in 1, 2, 2-3 or 2-4 (for forward motion) or 1 or 2 (for reverse motion)				(01)	Detroit Diesel Allison Opns and Maint. Instr. for X 1100 transmission and Final Drive (Apr 77) indicate all forward gears will permit automatic change to a higher gear (≤ 4) to prevent engine damage from excessive RPM. Can this be a control problem on long slopes or precipitous terrain? Driver cannot travel in reverse (in congested area) without front and rear guides (two).	Driver must maintain close communications with guides (one front and one rear) in reverse.	Vehicle can move from standing start in any gear. Reverse 1 will normally be used for slow back-up; reverse 2 will be fast. Reverse gears are not automatic. (No visibility to side or rear.)
37		ATD	Release foot BRAKE				(01)			
38		AMD (IMD)	Steer vehicle as it moves out				(00)	Is N (neutral) a problem if accidentally engaged during movement? Will vehicle go into neutral steer (pivot turn) or previous direction? There may be some interference in training reverse turns. Interference will come	Driver must understand relationship between S-BAR position and drive power inputs to tracks.	FORWARD  REVERSE Steer (s) bar turn diagram.

UNIT: HIMAG Crew
TASK: Drive
SUBTASK: Start

No	Inter-related Operation	Step	Driver Action	Step	TC Action	Feedback (+ Fault Info) & Correction	(Time) Cumulative	Potential Problems	Knowledge/Skill Requirements	Notes
38	(cont)							From auto driver training habits transferred to steering HIMAG.		
39		IMD G or N (AND)	Check STEER response			N TBD	(10)			
40		IMD G or N (AND)	Check GEAR shift			Sudden changes in speeds with gear down-shifting TBD. How determines N. If N, maintenance is required. How determine N?	(30)			
41		IMD G or N (AND)	Check FOOT BRAKE			Check for even pull and control. How determine? If N, maintenance is required.	(30)			
42		IMD G or N (AND)	Check HAND (PARK) BRAKE			Check for ability to slow vehicle at low speeds. How determine N?	(30)	Applying full (90°) PARK position during movement may result in locked wheel skid.		HAND (PARK) BRAKE can be used to slow vehicle or stop it instead of the FOOT BRAKE by pulling lever toward driver. Less than 90° position (PARK) will ordinarily be sufficient for BRAKING action. 90° (PARK) locks road wheels and is to be used only for parking.

UNIT: HIMAC Crew
TASK: Drive
SUBTASK: Stop

No	Inter-related Operation	Step	Driver Action	Step	TC Action	Feedback (& Fault Info) & Correction	(Time) Cumulative	Potential Problems	Knowledge/Skill Requirements	Notes
1		ATD	Release ACCEL				(01)			Assume completion of START subtask. HIMAC will gear down automatically.
2		ATD (WTD)	Press foot BRAKE to full stop and HOLD till Step 9				(05)		Gradual application of brake for smooth stop.	
3		AMD	Shift GEAR lever to N				(01)			
4		AMG G or N (DMM)	Check S-BAR in center position			If N, center S-BAR.	(02)	S-BAR must be in center position to avoid unwanted pivot turn if brake is released. Center position is not clearly indicated.	Driver must understand pivot turn procedures.	HIMAC will pivot turn in N if S-BAR off center. Is lack of center indicator a problem?
5		ATD	Insert S-BAR center position PIN in lock position			This insures that S-BAR remains in center position avoiding accidental pivot turn.	(02)			
6		WUD G or N (DUD)	Idle down engine (prior to Step 8)			Idle down (G) status is indicated by about 1200 RPM on tach and changed sound of engine. (If N wait further before Step 8.)				Experienced driver may learn to recognize idle down from auditory cues only.
7		ATD	Pull HAND BRAKE to PARK			90° position is PARK.	(02)			

UNIT: XIMAC Crew
TASK: Drive
SUBTASK: Stop

No.	Inter-related Operation	Step	Driver Action	Step	TC Action	Feedback (& Fault Info) & Correction	(Time) Cumula-tive	Potential Problems	Knowledge/Skill Requirements	Notes
8		ATD	After idle down switch ENGINE FUEL SHUTOFF and HOLD up till engine stops			Engine stops running. (If driver incapacitated or if electrical fuel shutoff fails, engine can be shutoff by TC operating manual fuel shutoff.				How long (much time) till engine stops?
9		ATD	Release FOOT BRAKE				(01)			
10		ATD	Turn OFF MASTER BATTERY switch (unless continued operation of system or sub-systems is desired)			MASTER BATTERY light goes OFF.	(01)			If continued operation of electrical system is desired (with engine OFF) fuel pump switch should be turned off. (Fuel pump switch is otherwise, left ON while parked.)

UNIT: HIMAG Crew
TASK: Drive
SUBTASK: Rough Terrain Driving (Vertical Obstacle)

No.	Inter-related Operation	Step	Driver Action	Step	TC Action	Feedback (& Fault Info) & Correction	(Time) Cumulative	Potential Problems	Knowledge/Skill Requirements	Notes
1		DFS G or M	Assure completion of START subtask through and including Step 34 with special consideration for Steps 28 and 30 (See notes)			If M, complete START subtask.		Appropriate track tension and chassis height for rough terrain driving remains TBD. Increased track tension may not be desirable for high speed cross-country operations. (TBD)	May move all three chassis height/trim levers at once to raise height uniformly.	START subtask Step 28 (track tension check and adjustment) and Step 30 (adjustment of chassis height and trim) may require special consideration for rough terrain driving. Height higher than STATIC may be desired to avoid hanging up on ridges or in troughs. Steps 28 and 30 can be done before or after beginning movement. However, it is, presumably, simpler to control vehicle during such adjustments if stationary, and this is procedure assumed here.
2		AND	Place GEAR shift lever in 1 or 2-1 (for forward motion) or 1 or 2 (for reverse)							
3		ATG	Release foot BRAKE							
4		AND (TBD)	Steer vehicle as it moves out							
5		DND G or M (AND)	*Check STEER response			M TBD		See START subtask for TBD questions 38, 39, 40, 41 (re 5, 6, 7, 8, respectively).		*Starred Steps (5, 6, 7, 8) can be omitted if performed on previous START.
6		DND G or M (AND)	*Check GEAR shift:			Sudden changes in speeds with gear down-shifting TBD. If M, maintenance is required.				

UNIT: BIMAC Crew
TASK: Drive
SUBTASK: Rough Terrain Driving (Vertical Obstacle)

No.	Inter-related Operation	Step	Driver Action	Step	TC Action	Feedback (& Fault Info) & Correction	(Time) Cumula-tive	Potential Problems.	Knowledge/Skill Requirements	Notes
7		DTD G or N (ATD)	*Check foot BRAKE			Check for even pull and control. If N, maintenance is required.				
8		DTD G or N (ATD)	*Check HAND (PARK) BRAKE			Check for ability to slow vehicle at low speeds.				What if N? What is N?
9		DTD (ATD)	Reduce SPEED (release ACCEL) and GEAR down to 1 as obstacle is approached at 90°					If both tracks do not meet face of obstacle nearly at once (near 90°) then vehicle may not have sufficient traction pull up and over.		
10		AND	Adjust ACCEL and/or FOOT BRAKE to pause at base of obstacle							
11		ATD (DTD)	Press ACCEL slowly to climb track over top							
12		ATD (DTD)	Continue sufficient power (ACCEL pressure) to surmount obstacle							
13		ATD (DTD)	Reduce ACCEL pressure to slow down as vehicle pitches over and rear road wheels climb down							Must use engine drag, not brakes, for maintenance of control of descent.
14		AND	Shift GEAR to 2-3 (or 2 if reversing swiftly)							
15		ATD	Resume appropriate speed by pressing ACCEL							

UNIT: XIMAG Crew
TASK: Drive
SUBTASK: Rough Terrain Driving
(Ditch Crossing)

No.	Inter-related Operation	Step	Driver Action	Step	TC Action	Feedback (& Fault Info) & Correction	(Time) Cumulative	Potential Problems	Knowledge/Skill Requirements	Notes
1		DFN G or N	Assure completion of START subtask through and including Step 34 with special consideration for Steps 28 and 30			If N, complete START subtask.		Appropriate track tension and chassis height for rough terrain driving remains TBD. Increased track tension may not be desirable for high speed cross-country operations. (TBD)	May move all three chassis height/trim levers at once to raise height uniformly.	See notes on VERTICAL OBSTACLE subtask re track tension adjustment and height/trim adjustments.
2		AMD (DMD)	Place GEAR shift lever in 1 or 2-3 (forward)							
3		ATD	Release FOOT BRAKE							
4		AMD (DMD)	Steer vehicle as it moves out							
5		DMD G or N (AMD)	*Check STEER response			N TBD		See START subtask for TBD questions 38, 39, 40, 41 (re 5, 6, 7, 8, respectively).		*Starred steps (5, 6, 7, 8) can be omitted if performed on previous start.
6		DMD G or N (AMD)	*Check GEAR shift			Sudden changes in speeds with gear down-shifting TBD. If N, maintenance is required.				
7		DTD G or N (ATD)	*Check FOOT BRAKE			Check for even pull and control. If N, maintenance is required.				
8		DTD G or N (ATD)	Check HAND (PARK) BRAKE			Check for ability to slow vehicle at low speeds				

UNIT: ?IMAC Crew
TASK: Drive
SUBTASK: Rough Terrain Driving
(Ditch Crossing)

No.	Inter-related Operation	Step	Driver Action	Step	TC Action	Feedback (& Fault Info) & Correction	(Time) Cumula-tive	Potential Problems	Knowledge/Skill Requirements	Notes
9		DTD (ATD)	Reduce SPEED (release ACCEL) and GEAR down to 1 as ditch edge is approached at 90°							If both tracks do not go over edge at once (near 90°) there is greater likelihood of side-slipping or throwing a track on descent.
10		ATD (DTD)	Adjust ACCEL to crawl (low speed) over edge till nose drops in							
11		ATD (DTD)	Press ACCEL to provide increased traction through bottom							
12		ATD (DTD)	Continue sufficient power (press ACCEL) to climb up far side							
13		AMD (AMD)	Adjust STEERING for climb-out at 90°			Best control on climb-out will be at angle near 90°				
14		ATD (DTD)	Reduce ACCEL pressure to slow down track as vehicle pitches over and rear road wheels climb out							
15		AMD	Shift GEAR to 2-3 or 2-4							
16		ATD (DTD)	Resume appropriate speed by pressing ACCEL							

USIT: HIMAG Crew
TASK: Drive
SUBTASK: Pivot turn
(Neutral steep turn)

No	Inter-related Operation	Step	Driver Action	Step	TC Action	Feedback (& Fault Info) & Correction	(Time) Cumula-tive	Potential Problers	Knowledge/Skill Requirements	Notes
1				TID	COMMANDS-DRIVER, NEUTRAL STEER TURN RIGHT (OR LEFT) AND ANGLE DESIRED					
2		ATD	Release ACCEL				(01)			Assume completion of START subtask.
3		ATD G or N (DTD) (WTD)	Press foot BRAKE until fully stopped. Hold during Steps 3 and 4			If N (not fully stopped) remain in drive gear until complete stop.	(05)	Shifting GEAR lever to N prior to full stop and centering S-BAR may result in accidental pivot turn.		
4		AMN (DMN)	Center S-BAR				(01)	Center position for S-BAR is not clearly indicated (See notes above.		
5		AMD	Shift GEAR lever to N				(02)			
6		ATD	Release BRAKE pedal				(01)			
7		AMD (DMD) (WMD)	Turn S-BAR fully (clockwise) for right; or (counter-clockwise) for left pivot turn, and HOLD			Rate of turn will depend upon S-BAR adjustment and pressure on ACCEL.	(02)			Full Steer (S-BAR) turn and . . .
8		ATD	Press ACCEL slowly, moderately, until turn is completed				(10)			Smooth, moderate ACCEL pressure are ordinarily desirable.
9		AMN	Return S-BAR to center position (when turn is completed)				(01)			No braking is necessary in coordinated performance.
10		ATD	Release ACCEL				(01)			

APPENDIX B

PREDICTIONS RE OPERATOR PERFORMANCES

PREDICTIONS RE OPERATOR PROBLEMS

SUBTASK	(FROM OS/TA)	FROM HF OBSERVATIONS
Start	(a) D must center S-bar and drop pin into lock position to insure against accidental pivot. Center position is unmarked except for pin-fit position. Center position will be difficult to find; will require more than 4 seconds to center S-bar and drop pin into lock position. (1) (b) D's first use of BRAKE pedal uses left foot, an exception to general rule that right foot is used on BRAKE and on ACCEL, alternately, as in auto driving. May result in repeated attempts to use left foot on BRAKE during movement, and changing feet on BRAKE in this operation. (Training emphasis.) (2) (c) Steps 11, . . . 15,16,17,18,19,20 (press f. brake, master battery, starter, manifold heat) involve coordination of both feet and both hands in simultaneous operations while estimating elapsed time on two concurrent events. This sequence appears to require extraordinary coordination and time sharing control by D. It will likely be beyond the capabilities of most drivers for learning in a short course. Errors in this sequence will persist at end of training and after training. (3) (Training emphasis, and, possibly, added instrumentation--retrofit.)	
Stop	D's first use of BRAKE pedal uses left foot, an exception to general rule. (See START subtask above.) This experience will probably result in repeated attempts to use left foot on BRAKE pedal during movement, primarily in training. (1) (Training emphasis.)	

SUBTASK	FROM OS/TA	FROM HF OBSERVATIONS
Neutral Steer Turn (Pivot Turn)		Starting and stopping pivot turn will be most difficult parts of subtask because S-bar control positions are not marked. S-bar is primary control (not brake pedal) in pivot turn. Difficulty in controlling start and stop of pivot turn is likely to continue beyond training. (2) (Control-display redesign-retrofit and, possibly, operational sequence changes and training emphasis.)
Rough Terrain Driving—Vertical Obstacle		D has potential capability for adjusting track tension and adjusting height/trim for different types of terrain and operations. However, doctrine for use is undeveloped and gauge markers are very crude or lacking on both gauges. These two systems will require field gauge markings and field-expedient doctrine development during training and testing. (3) (Doctrine development and controls redesign-retrofit)
Rough Terrain Driving—Ditch Crossing		Track tension and height/trim adjustments will present difficulties because of lack of doctrine for use and poor gauge markers. (See above.) Driver will require extraordinary assistance and guidance on use of these controls. (3) (Doctrine development and controls redesign-retrofit.)
Driving on Smooth Surface—Level		Driver must understand relationships between S-bar positions and drive power inputs to -racks. Reverse is opposite to auto steering conventions. Interference from auto driving habits will cause prolonged, repeated errors in steering in REVERSE gear. (1) (Training emphasis.)

SUBTASK	FROM OS/TA	FROM HF OBSERVATIONS
Driving on Smooth Surface—Hill		Detroit Diesel Allison Opns and Maint Instr. for X1100 transmission and final drive (Apr 77) indicates all forward gears will permit automatic change to a higher gear ($\leq$ 4) to prevent engine damage from excessive RPM. Automatic up-change in gear during long downhill course will likely result in loss of control and excessive high speeds. (3) (Machine components redesign-retrofit.)

APPENDIX C

DATA COLLECTION FORMS, HIMAG DRIVER

DRIVER PERFORMANCE EVALUATION FORM
VEHICLE DRIVER'S INTERVIEW FORM
HIMAG CREW OPERATIONS QUESTIONS
HIMAG CHASSIS TEST CRITICAL INCIDENT
FILM REVIEW INCIDENT REPORT

HIMAG CHASSIS TEST
Data Collector's Form
Driver Performance Data
(Training, Hit Avoidance, 15km dash)

DRIVER PERFORMANCE EVALUATION FORM

Driver ID______________________ System________ Date__________

Check left hand blank if task is attempted during trial. Place check mark in the appropriate right hand blank for each error. Same blank may be checked more than once if error is repeated on same trial or run.

I. START AND STOP

_____ A. Start (time _____)

Fails to FASTEN and ADJUST SAFETY BELTS _______
Fails to set GEAR in N . . . . _______
Fails to CENTER STEER bar _______
Fails to HOLD STARTER after press (≠ 30 sec) . . _______
Fails to WAIT for engine WARM-UP (5 min) _______
Fails to RELEASE PARK brake . . . . . . _______

1	2	3	4	5	6	7	8	9
Very Poor Task Performance		Needs Improvement		Acceptable		Good		Outstanding Task Performance

_____ B. Stop (time _____)

Fails to PRESS BRAKE smoothly and HOLD _______
Fails to SHIFT GEAR to N . . . . . . _______
Fails to CENTER STEER BAR _______
Fails to IDLE DOWN engine . . . . . . _______
Fails to put ON PARK brake . . . . . _______
Fails to HOLD up ENGINE FUEL SHUTOFF after switching . . _______

1	2	3	4	5	6	7	8	9
Very Poor Task Performance		Needs Improvement		Acceptable		Good		Outstanding Task Performance

II. DRIVING ON SMOOTH SURFACE

_____ A. Level

Changes SPEED excessively _______
BRAKES rough or too MUCH . . . . . . _______
ACCELERATES too FAST _______
OVERSTEERS . . . . _______
STEERS WRONG way _______
Loses CONTROL . . . . _______

1	2	3	4	5	6	7	8	9
Very Poor Task Performance		Needs Improvement		Acceptable		Good		Outstanding Task Performance

_____ B. Hill

Changes SPEED excessively . . . . ______
Fails to SELECT correct GEAR . . . . ______
BRAKES rough or too MUCH . . . . ______
ACCELERATES too FAST . . . . ______
EXCESS SPEED . . . . ______
Loses CONTROL . . . . ______

1	2	3	4	5	6	7	8	9
Very Poor Task Performance		Needs Improvement		Acceptable		Good		Outstanding Task Performance

_____ C. Pivot Turn

Fails to SHIFT GEAR to N . . . . ______
Fails to CENTER STEER bar . . . . ______
Fails to turn STEER bar FULL extent . . . . ______
Turns WRONG way . . . . ______
Fails to ACCELERATE slowly, smoothly . . . . ______
STOPS by braking . . . . ______

1	2	3	4	5	6	7	8	9
Very Poor Task Performance		Needs Improvement		Acceptable		Good		Outstanding Task Performance

III. DRIVING ON ROUGH TERRAIN

_____ A. Vertical obstacle crossing

Approaches TOO FAST . . . . ______
Approaches obliquely (not 90°) . . . . ______
Uses WRONG GEAR (not 1) . . . . ______
Fails to check/adjust HEIGHT . . . . ______
Fails to check/adjust TENSION . . . . ______
PITCHES OVER hard . . . . ______

1	2	3	4	5	6	7	8	9
Very Poor Task Performance		Needs Improvement		Acceptable		Good		Outstanding Task Performance

_____ B. Ditch crossing

Approaches TOO FAST . . . . _____
Approaches obliquely (not 90°) . . . . . _____
Uses WRONG GEAR (not 1) . . . . _____
Fails to check/adjust HEIGHT . . . . . . _____
Fails to check/adjust TENSION . . . . . _____
BOTTOMS out or PITCHES OVER hard . . . . _____

1	2	3	4	5	6	7	8	9
Very Poor Task Performance		Needs Improvement		Acceptable		Good		Outstanding Task Performance

TEST OPERATION RECORD	PROJECT NO 7-ØØØØ23	DATE (DA/MO/YR)
NOMENCLATURE HIMAG CHASSIS TEST VEHICLE DRIVER'S INTERVIEW FORM	IDENTIFICATION NO DATA COLLECTOR NAME	

[ ][ ][ ][ ][ ] [ ][ ][ ][ ] [ ][ ] [ ] [ ]

01 JULIAN DATE 05 06 TRIAL 09 VEHICLE CONFIGURATION 10 11 COURSE 12 MANEUVER 13

EVENT (cc 14)
[ ] 1=TRAINING
[ ] 2=CONTROLLED SLALOM
[ ] 3=15 KM
[ ] 4=HIT AVOIDANCE

CREW ID 15 16 17 DRIVER'S LAST NAME 26 27 CODE 30

VEHICLE TYPE (cc 31)
[ ] 1=M60A1
[ ] 2=M113
[ ] 3=HIMAG

BUMPER NUMBER 32 34

cc	
35	Did the vehicle go as fast as you wanted it to go? [ ] 1=YES [ ] 2=NO
36	If no, why? [ ] 1=Terrain too rough. [ ] 2=Had difficulty braking. [ ] 3=Couldn't see far enough ahead. [ ] 4=Turns in course were too sharp. [ ] 5=Couldn't see right in front of vehicle. [ ] 6=There was track slippage. [ ] 7=Couldn't see front corners of vehicle. [ ] 8=Had difficulty steering
44	[ ] 9=Other (specify)
45	Did anything (else) hinder your performance during this trial? [ ] 1=No [ ] 2=Vegetation [ ] 3=Glare [ ] 4=Fog [ ] 5=Dust [ ] 6=Smoke
51	[ ] 7=Other (specify)
52	Do you think you could have run this trial any better? [ ] 1=YES [ ] 2=NO
53	If yes, how much better? 1[ ] SLIGHTLY BETTER 2[ ] 3[ ] 4[ ] 5[ ] MUCH BETTER
54	Discribe any unusual performance, occurance, or failures: (IF TEXT, PUNCH 1)
55	Which best describes the jolts and bumps at the driver's seat? 1[ ] VERY ROUGH 2[ ] ROUGH 3[ ] AVERAGE 4[ ] GOOD 5[ ] VERY SMOOTH
56	Which best describes the vehicle vehicle vibration and shaking? 1[ ] VERY SHAKY 2[ ] SHAKY 3[ ] AVERAGE 4[ ] LOW 5[ ] VERY LITTLE
57	Which best describes the noise level before moving? 1[ ] VERY NOISY 2[ ] NOISY 3[ ] AVERAGE 4[ ] QUIET 5[ ] VERY QUIET
58	Which best describes the noise level during the trial? 1[ ] VERY NOISY 2[ ] NOISY 3[ ] AVERAGE 4[ ] QUIET 5[ ] VERY QUIET

59 In your own words, how did the ride feel? (IF TEXT, PUNCH 1)

Indicate the degree of difficulty or ease in performing the following operations.

		VERY DIFFICULT	DIFFICULT	NEUTRAL	EASY	VERY EASY
60	Operation of shift lever	1[]	2[]	3[]	4[]	5[]
61	Getting up to speed	1[]	2[]	3[]	4[]	5[]
62	Braking	1[]	2[]	3[]	4[]	5[]
63	Steering	1[]	2[]	3[]	4[]	5[]
64	Maintaining steady speed	1[]	2[]	3[]	4[]	5[]
65	Driving a straight line	1[]	2[]	3[]	4[]	5[]
66	Turning	1[]	2[]	3[]	4[]	5[]
67	General operation of vehicle	1[]	2[]	3[]	4[]	5[]

68 Explain the difficulties in your own words. (IF TEXT, PUNCH 1)

Did you find any of the following especially difficult during this trial, or do you feel that you performed the task poorly?

		OK & EASY	NOT DONE	DIFFICULT	POORLY DONE	BOTH (2&3)
69	Starting	0[]	1[]	2[]	3[]	4[]
70	Stopping	0[]	1[]	2[]	3[]	4[]
71	Level road march	0[]	1[]	2[]	3[]	4[]
72	Hill road climb and descend	0[]	1[]	2[]	3[]	4[]
73	Terrain ditch crossing	0[]	1[]	2[]	3[]	4[]
74	Terrain vertical obstacle	0[]	1[]	2[]	3[]	4[]
75	Neutral steer turn	0[]	1[]	2[]	3[]	4[]
76	Reading speedometer	0[]	1[]	2[]	3[]	4[]
77	Reading other instruments	0[]	1[]	2[]	3[]	4[]
78	Turning controls and switches	0[]	1[]	2[]	3[]	4[]

79 Explain the difficulties in your own words. (IF TEXT, PUNCH 1)

HIMAG CREW OPERATIONS QUESTIONS

It is important to identify the operational problems in the HIMAG chassis as early as possible so that the system and the training can be improved for the tests. Your candid answers to the following questions will be helpful.

1. STARTING

a. In STARTING up the HIMAG what were the main difficulties, if any? Please explain in your own words.

____

____

____

____

b. Rate the above problem(s): Rating ________

(1) minor, (2) severe, or (3) very severe, major problem

c. In STARTING up the HIMAG did any of the following present difficulties? (Rate each one: (0) no problem, or (1), (2) or (3).

	Rating
(i) Centering S-BAR and dropping pin into position	________
(ii) Operating BRAKE pedal	________
(iii) Simultaneous control of BRAKE and ACCELERATOR pedals along with STARTER button and MANIFOLD HEAT switch manipulation and timing	________

2. STOPPING

a. In STOPPING the HIMAG what were the main difficulties, if any? Please explain in your own words.

____

____

____

____

b. Rate the above problem(s): Rating________

(1) minor, (2) severe, or (3) very severe, major problem.

c. In STOPPING the HIMAG did operation of the BRAKE pedal present difficulties? Rating________

Rate: (0) no problem, or (1), (2), or (3).

3. NEUTRAL STEER (PIVOT) TURN

a. In PIVOT TURN what were the main difficulties, if any? Please explain in your own words.

____

____

____

____

b. Rate the above problem(s): Rating__________
(1) minor, (2) severe, or (3) very severe, major problem.

c. In PIVOT TURN was it difficult to start and/or stop turn without braking (using S-bar control only)? Rating__________
Rate: (0) no problem, or (1), (2), or (3).

4. ROUGH TERRAIN-VERTICAL OBSTACLE AND/OR DITCH CROSSING

a. In VERTICAL OBSTACLE and/or DITCH CROSSING what were the main difficulties, if any? Please explain in your own words.

____

____

____

____

b. Rate the above problem(s): Rating__________
(1) minor, (2) severe, or (3) very severe, major problem.

c. In ROUGH TERRAIN-VERTICAL OBSTACLE and/or DITCH CROSSING did any of the following present difficulties?
(Rate each one: (0) no problem, or (1), (2) or (3))

	Rating
(i) Height/trim adjustment	________
(ii) Track tension adjustment	________

5. SMOOTH SURFACE-LEVEL

a. In SMOOTH SURFACE-LEVEL driving what were the main difficulties, if any? Please explain in your own words.

____

____

____

____

b. Rate the above problem(s): Rating________

(1) minor (2) severe, or (3) very severe, major problem.

c. In SMOOTH SURFACE-LEVEL driving was it difficult to steer correctly in reverse? Rating____________

Rate: (0) no problem, or (1), (2) or (3).

6. SMOOTH SURFACE-HILL

a. In SMOOTH SURFACE-HILL driving what were the main difficulties, if any? Please explain in your own words.

____

____

____

____

b. Rate the above problem(s): Rating____________

(1) minor (2) severe, or (3) very severe, major problem.

c. In SMOOTH SURFACE-HILL driving was it difficult to control gears, gear changes and speeds? Rating____________

Rate: (0) no problem, or (1), (2), or (3).

7. Please number the following in order of difficulty you had in doing them correctly. Place number 1 before the subtask which was most difficult to do correctly, number 2 before the next most difficult, . . . etc., using all the numbers, 1 to 6, giving 6 to the easiest subtask.

_____ Stopping

_____ Starting

_____ Rough Terrain - Vertical Obstacle or Ditch

_____ Downhill Driving

_____ Neutral Steer (Pivot) Turn

_____ Smooth Surface Level Driving

TEST OPERATION RECORD

TEST OPERATION RECORD	PROJECT NO 7-[illegible]	DATE [illegible]
NOMENCLATURE HIMAG CHASSIS TEST CRITICAL INCIDENT	IDENTIFICATION NO DATA COLLECTOR NAME	

7 3 — 01 JULIAN DATE 05 — 06 TRIAL 09 — VEHICLE CONFIGURATION 10 11 — COURSE 12 — MANEUVER 13

EVENT (cc 14)
[] 1=TRAINING
[] 2=CONTROLLED SLALOM
[X] 3=15 KM
[] 4=HIT AVOIDANCE

CREW ID 15 16 — 17 DRIVER'S LAST NAME 26 — 27 CODE 30

VEHICLE TYPE (cc 31)
[] 1=M60A1
[] 2=M113
[] 3=HIMAG

BUMPER NUMBER 32 34

A. General

1. How did incident occur?

2. What were crewmen doing at the time?

3. What was vehicle/system doing at the time?

4. Remarks:

B. Vehicle damage or accident

1. Describe damage.

2. Was vehicle disabled? ___ Y N

3. Recovery . . . VTR required? ___ Y N

4. Time out of service:

C. Crew injury

1. Crew-position of injured:

2. Describe injury.

3. How severe? Slight — Mild — Moderate — Severe — Very severe

D. Near-miss

1. Describe what happened.

2. What was potential damage or injury?

3. Additional remarks:

ATZK-AE FORM 1 Oct 75 3859 — AG 9646-O-Army-Knox-Nov 75-1?

Film Review Incident Report

Driver's Name ______________________ Last 4 ________________

Run Date __________________ Ground Condition __________________

Trial Number ______________

Where on 20km course did the incident occur?

What was the driver attempting to do?

What instructions had the TC given just before the incident?

How serious was the incident?

1	2	3	4	5
Slight		Moderate		Severe

How much did the driver's actions contribute to the incident? ________%

What were those actions?

How much did the vehicle contribute to the incident? ________%

What did the vehicle do?

How much did the terrain contribute to the incident? ________%

APPENDIX D

HIMAG DRIVER STATION FACTORS

HIMAG DRIVER STATION

In this section, engineering design features specific to the HIMAG vehicle are reported. Based upon the author's judgments these features are discriminated from those (in the text above) considered to be more generic to a class of high speed tracked vehicles. Some of these are mentioned above, and, of course, some of these characteristics may also be found in other driver stations involving similar designs or components.

The HIMAG ride was generally regarded as superior to the M60A1 or M113 ride. Relatively few drivers described the HIMAG jolts and bumps as "rough" or "very rough" as compared with M113 drivers. The HIMAG was described as less "shaky" than the M60A1 or M113. Despite occasional reports of HIMAG "bottoming out" or "bouncing" the ride was usually described as "good," ... "smooth," ... "comfortable," ... "outstanding," ... "much better than in M60." However, there were some complaints about shock absorption at high speeds or over rough terrain.

Driver seating was not evaluated here because the experimental seats were the subject of a special evaluation by US Army Human Engineering Laboratory. Some of the drivers experienced seat suspension failures and some reported later that they drove over parts of the 20 km course in a braced position above (or resting lightly on) the seat, a posture posing unknown limitations upon overall driver performance.

Possibly the most severe limitation upon HIMAG driver performances in the 20 km test resulted from the inadequate windshield wiper/washer operating in a generally wet, muddy environment. Vision limitations by mud on the windscreens was reported after two-thirds of the trials. Most of the HIMAG critical incidents (55%) occurred on 9% of the 20 km course characterized by sharp turns and (often) mud surfaces. (Excess speed driving and some brake failures were also associated with some of these incidents.) Obscuration of peripheral vision may have severely handicapped HIMAG drivers on these slippery mud surfaces with sharp turns.

Aside from the field of view limitations due to mud obscuration there was only one complaint involving displays, i.e., the location of the speedometer. About one fourth of the drivers mentioned after training and after the 20 km test that the speedometer location required them to look away from the windscreen so they didn't use the speedometer. However, almost all reported that reading the speedometer was "done easily" after the 20 km trials. The location - behind the steering gear - apparently caused some inconvenience to which they adjusted - in some cases (6 of 23) by not reading it.

The track tension and height adjustment controls were used rarely and only on the specific instruction of the NWL trainer (during training). It appears that doctrine or standard procedures for these controls was not yet developed as was predicted in the pre-training analysis. One trainee mentioned that the track tension controls were "...very hard to get to when vehicle is moving."

Both the brake pedal and the accelerator pedal were subjects of complaints after training. More than half the drivers complained after training (and a somewhat smaller number after 20 km test trials) about the hard pressure required on the brake pedal and the "sensitive," "powerful" braking response of the HIMAG. Complaints suggested that the braking response should be made more nearly linear in its relationship to control pedal force.

The accelerator angle caused some discomfort (according to more than 25% of the drivers) and this discomfort may have increased after prolonged driving, according to some incidental reports received. Some muscle strain was involved in keeping the foot on the accelerator (keeping from slipping off).

For other complaints about steering, power response and shock absorption, see Table 18 (Appendix E).

APPENDIX E

SUMMARY OF DRIVER INTERVIEW DATA

SUMMARY OF DRIVER INTERVIEW DATA

The following item responses yielded very small subsamples appropriate only for descriptive statistical analysis. The data to follow are worthy of examination for relative concurrence or trends with the recognition that differences among vehicles are generally not statistically significant.

Selected items from the post-trial driver interviews are presented in Table 17. 1978 and 1979 data are merged in order to maximize the samples. Samples are made up of post-trial interviews, within which a few drivers were represented more than once. Figures are percents followed (in parentheses) by actual number of responses.

TABLE 17

POST-TRIAL RESPONSES OF DRIVERS (PERCENT AND (NUMBER)) TO STRUCTURED INTERVIEW ITEMS: 1978 AND 1979 DATA MERGED. ITEMS REQUIRING VERBAL DESCRIPTION ARE MERELY REPORTED AS NUMBER OF RESPONSES. (SEE TABLE 20 FOR SUMMARY OF VERBAL ITEMS.)

HIMAG CHASSIS TEST 20 KM COURSE DRIVER INTERVIEW RESPONSES

	CONFIGURATION			
	M60A1	M113	05	02
	n=26	n=22	n=11	n=11
QUESTION				
1. Did you have enough driving time on the vehicle to prepare you for driving the 20 kilometer course?				
Yes.	61.5(16)	45.5(10)	81.8(9)	81.8(9)
No.	3.9(1)	36.4(8)	9.1(1)	18.2(2)
No response or don't know.	34.6(9)	18.2(4)	9.1(1)	0
2. If you had more operating time experience on the vehicle, could you have driven the 20 kilometer course faster?				
Yes.	26.9(7)	59.1(13)	63.6(7)	72.7(8)
No.	50.0(13)	22.7(5)	27.3(3)	27.3(3)
No response or don't know.	23.1(6)	18.2(4)	9.1(1)	0

QUESTION	CONFIGURATION			
	M60A1	M113	05	02
	n=26	n=22	n=11	n=11
3. If you drive the course again, how will your driving time change?				
Very much faster.	11.5(3)	0	9.1(1)	9.1(1)
Faster.	11.5(3)	31.8(7)	27.3(3)	36.4(4)
Somewhat faster.	50.0(13)	45.5(10)	27.3(3)	27.3(3)
No change.	23.1(6)	4.5(1)	9.1(1)	18.2(2)
Somewhat slower.	0	0	0	9.1(1)
Slower.	0	0	0	0
Very much slower.	0	0	0	0
4. Did the vehicle go as fast as you wanted it to go?				
Yes.	15.4(4)	9.1(2)	63.6(7)	90.9(10)
No.	46.2(12)	68.2(15)	36.4(4)	9.1(1)
No response or don't know.	38.5(10)	22.7(5)	0	0
If no, why?				
Terrain too rough?	26.9(7)	13.6(2)	9.1(1)	0
Had difficulty braking.	3.9(1)	13.6(2)	0	0
Couldn't see far enough ahead.	0	0	0	0
Turns in course were too sharp.	0	0	0	0
Couldn't see right in front of vehicle.	0	0	0	0
There was track slippage.	7.7(2)	9.1(2)	9.1(1)	9.1(1)
Couldn't see front corners of vehicles.	0	0	0	0
Had difficulty steering.	0	18.2(4)	9.1(1)	0
Other.	42.3(11)	77.3(17)	18.2(2)	0

	CONFIGURATION			
	M60A1	M113	05	02
	n=26	n=22	n=11	n=11
QUESTION				
5. Did anything (else) hinder your performance during this trial?				
Yes.	46.2(12)	45.5(10)	81.8(9)	54.5(6)
No.	53.8(14)	54.5(12)	18.2(2)	45.5(5)
Vegetation.	0	0	0	0
Glare.	3.9(1)	0	0	9.1(1)
Fog.	0	0	0	0
Dust.	3.9(1)	0	0	0
Smoke.	0	0	0	0
Other.	30.8(8)	45.4(10)	72.7(8)	54.5(6)
6. Do you think you could have run this trial better?				
Yes.	69.2(18)	90.9(20)	72.7(8)	81.8(9)
No.	23.1(6)	9.1(2)	27.3(3)	18.2(2)
If yes, how much better?				
1-Slightly better.	23.1(6)	9.1(2)	0	18.2(2)
2-	19.2(5)	31.8(7)	36.4(4)	9.1(1)
3-	7.7(2)	36.4(8)	0	36.4(4)
4-	3.9(1)	9.1(2)	27.3(3)	27.3(3)
5-Much better.	11.5(3)	4.6(1)	18.2(2)	0

	CONFIGURATION			
	M60A1	M113	05	02
QUESTION	n=26	n=22	n=11	n=11
7. Describe any unusual performance, occurrence or failures.	38.5(10)	36.4(8)	90.9(10)	90.9(10)
8. Which best describes the jolts and bumps at the driver's seat?				
Very rough.	0	4.6(1)	9.1(1)	0
Rough.	7.7(2)	31.8(7)	0	9.1(1)
Average.	50.0(13)	36.4(8)	36.4(4)	54.5(6)
Good.	26.9(7)	27.3(6)	27.3(3)	27.3(3)
Very smooth.	7.7(2)	0	18.2(2)	9.1(1)
9. Which best describes the vehicle vibration and shaking?				
Very shaky.	0	9.1(2)	0	0
Shaky.	7.7(2)	22.7(5)	18.2(2)	0
Average.	69.2(18)	54.5(12)	18.2(2)	45.5(5)
Low.	11.5(3)	13.6(3)	36.4(4)	54.5(6)
Very little.	3.9(1)	0	18.2(2)	0
10. Which best describes the noise level before moving.				
Very noisy.	3.9(1)	4.6(1)	0	0
Noisy.	7.7(2)	27.3(6)	27.3(3)	9.1(1)
Average.	65.4(17)	54.6(12)	36.4(4)	81.8(9)
Quiet.	15.4(4)	9.1(2)	27.3(3)	9.1(1)
Very quiet.	0	4.6(1)	0	0

	CONFIGURATION			
	M60A1	M113	05	02
	n=26	n=22	n=11	n=11
QUESTION				
11. Which best describes the noise level during the trial?				
Very noisy.	3.9(1)	27.3(6)	9.1(1)	0
Noisy.	15.4(4)	22.7(5)	27.3(3)	9.1(1)
Average.	61.5(16)	50.0(11)	36.4(4)	72.7(8)
Quiet.	11.5(3)	0	18.2(2)	9.1(1)
Very quiet.	0	0	0	9.1(1)
12. In your own words, how did the ride feel?	76.9(20)	100.0(22)	72.7(8)	100.0(11)
INDICATE THE DEGREE OF DIFFICULTY OR EASE IN PERFORMING THE FOLLOWING OPERATIONS:				
13. Operating of shift lever.				
Very difficult.	0	0	0	0
Difficult.	3.9(1)	13.6(3)	0	0
Neutral.	11.5(3)	31.8(7)	9.1(1)	0
Easy.	53.9(14)	36.4(8)	27.3(3)	45.5(5)
Very easy.	19.2(5)	9.1(2)	36.4(4)	54.5(6)
14. Getting up to speed.				
Very difficult.	11.5(3)	18.2(4)	0	9.1(1)
Difficult.	42.3(11)	31.8(7)	9.1(1)	18.2(2)
Neutral.	15.4(4)	27.3(6)	27.3(3)	18.2(2)
Easy.	19.2(5)	13.6(3)	36.4(4)	36.4(4)
Very easy.	0	0	0	9.1(1)

QUESTION	CONFIGURATION			
	M60A1	M113	05	02
	n=26	n=22	n=11	n=11
15. Braking.				
Very difficult.	0	9.1(2)	0	0
Difficult.	3.9(1)	13.6(3)	9.1(1)	18.2(2)
Neutral.	7.7(2)	31.8(7)	18.2(2)	0
Easy.	73.1(19)	36.4(8)	45.5(5)	72.7(8)
Very easy.	3.9(1)	4.6(1)	0	9.1(1)
16. Steering.				
Very difficult.	0	9.1(2)	9.1(1)	0
Difficult.	15.4(4)	9.1(2)	0	18.2(2)
Neutral.	19.2(5)	36.4(8)	0	0
Easy.	50.0(13)	31.8(7)	54.5(6)	54.5(6)
Very easy.	3.9(1)	9.1(2)	9.1(1)	27.3(3)
17. Maintaining steady speed.				
Very difficult.	19.2(5)	13.6(3)	0	0
Difficult.	23.1(6)	50.0(11)	18.2(2)	0
Neutral.	11.5(3)	13.6(3)	0	27.3(3)
Easy.	30.8(8)	18.2(4)	54.5(6)	54.5(6)
Very easy.	3.9(1)	0	0	18.2(2)

QUESTION	CONFIGURATION M60A1 n=26	M113 n=22	05 n=11	02 n=11
18. Driving a straight line.				
Very difficult.	0	9.1(2)	0	0
Difficult.	23.1(6)	13.6(3)	0	9.1(1)
Neutral.	15.4(4)	36.4(8)	0	9.1(1)
Easy.	46.2(12)	27.3(6)	72.7(8)	45.5(5)
Very easy.	3.9(1)	9.1(2)	0	36.4(4)
19. Turning.				
Very difficult.	0	4.5(1)	9.1(1)	0
Difficult.	11.5(3)	0	0	18.2(2)
Neutral.	7.7(2)	31.8(7)	36.4(4)	27.3(3)
Easy.	69.2(18)	50.0(11)	18.2(2)	27.3(3)
Very easy.	0	9.1(2)	9.1(1)	27.3(3)
20. General operation of vehicle.				
Very difficult.	0	0	0	0
Difficult.	3.9(1)	4.5(1)	0	9.1(1)
Neutral.	26.9(7)	31.8(7)	9.1(1)	0
Easy.	53.9(14)	45.5(10)	63.6(7)	72.7(8)
Very easy.	3.9(1)	9.1(2)	0	18.2(2)

	CONFIGURATION			
	M60A1	M113	05	02
	n=26	n=22	n=11	n=11
QUESTION				
21. Explain the difficulties in your own words.	50.0(13)	72.7(16)	36.4(4)	54.5(6)
DID YOU FIND ANY OF THE FOLLOWING ESPECIALLY DIFFICULT DURING THIS TRIAL, OR DO YOU FEEL THAT YOU PERFORMED THE TASK POORLY?				
22. Starting.				
Done easily.	23.1(6)	22.7(5)	63.6(7)	90.9(10)
Not done.	7.7(2)	9.1(2)	36.4(4)	0
Difficult.	0	0	0	0
Poorly done.	0	4.5(1)	0	9.1(1)
Both.	0	0	0	0
23. Stopping.				
Done easily.	26.9(7)	22.7(5)	72.7(8)	100.0(11)
Not done.	3.9(1)	9.1(2)	9.1(1)	0
Difficult.	0	13.6(3)	0	0
Poorly done.	0	0	18.2(2)	0
Both.	0	0	0	0
24. Level road march.				
Done easily.	11.5(3)	22.7(5)	81.8(9)	100.0(11)
Not done.	3.9(1)	4.5(1)	9.1(1)	0
Difficult.	15.4(4)	18.2(4)	9.1(1)	0
Poorly done.	0	4.5(1)	0	0
Both.	0	0	0	0

QUESTION	M60A1 n=26	M113 n=22	05 n=11	02 n=11
25. Hill road climb and descend.				
Done easily.	0	27.3(6)	63.6(7)	100.0(11)
Not done.	3.9(1)	4.5(1)	0	0
Difficult.	26.9(7)	9.1(2)	36.4(4)	0
Poorly done.	0	4.5(1)	0	0
Both.	0	0	0	0
26. Terrain ditch crossing.				
Done easily.	19.2(5)	27.3(6)	81.8(9)	90.9(10)
Not done.	15.4(4)	4.5(1)	9.1(1)	9.1(1)
Difficult.	0	4.5(1)	9.1(1)	0
Poorly done.	0	0	0	0
Both.	0	0	0	0
27. Terrain vertical obstacle.				
Done easily.	11.5(3)	27.3(6)	90.9(10)	90.9(10)
Not done.	23.1(6)	4.5(1)	9.1(1)	9.1(1)
Difficult.	0	4.5(1)	0	0
Poorly done.	0	0	0	0
Both.	0	0	0	0
28. Neutral steer turn.				
Done easily.	15.4(4)	18.2(4)	72.7(8)	90.9(10)
Not done.	15.4(4)	18.2(4)	9.1(1)	9.1(1)
Difficult.	3.9(1)	4.5(1)	9.1(1)	0
Poorly done.	0	0	9.1(1)	0
Both.	0	0	0	0

(Column group header: CONFIGURATION)

	CONFIGURATION			
	M60A1	M113	05	02
	n=26	n=22	n=11	n=11
QUESTION				
29. Reading speedometer.				
Done easily.	26.9(7)	27.3(6)	90.9(10)	90.9(10)
Not done.	3.9(1)	4.5(1)	9.1(1)	9.1(1)
Difficult.	0	9.1(2)	0	0
Poorly done.	0	0	0	0
Both.	0	0	0	0
30. Reading other instruments.				
Done easily.	19.2(5)	27.3(6)	90.9(10)	100.0(11)
Not done.	7.7(2)	4.5(1)	9.1(1)	0
Difficult.	3.9(1)	9.1(2)	0	0
Poorly done.	0	0	0	0
Both.	0	0	0	0
31. Turning controls and switches.				
Easily done.	26.9(7)	22.7(5)	90.9(10)	100.0(11)
Not done.	3.9(1)	13.6(3)	9.0(1)	0
Difficult.	0	4.5(1)	0	0
Poorly done.	0	0	0	0
Both.	0	0	0	0
32. Explain the difficulties in your own words.	26.9(7)	18.2(4)	45.5(5)	9.1(1)

TABLE 18

DRIVERS' EXPLANATIONS EXTRACTED FROM OPEN-END ITEMS IN POST-TRIAL INTERVIEWS. NUMBERS IN PARENTHESES INDICATED NUMBER OF DRIVERS WITH SIMILIAR RESPONSES. ITEM NUMBERS REFER TO QUESTIONS WHICH CALL FOR EXPLANATION IN TABLE 17, ABOVE.

4. Speed limitations. M60A1 and M113: Almost all reports concerned inadequate power on uphill grades. "Not enough power on uphill grades." (5 M60A1; 11 M113)

HIMAG: Vehicle may spring over rolling bumps, "bottomed out," "very bouncy." (6) Traction problems in mud, "sliding," "slipping," "sliding too much when making turns." (6) "Side windows mudded," "windshield wipers do not clean fast enough." (5) "No power going up hills, "lack of power" (5), "accelerator pedal at wrong angle." (3)

5. Hindrance to performance: M60A1 and M113: Mud, mud holes and consequent visual obscuration by water and mud. (5 M60A1, 12 M113)

HIMAG: "mud" (11). "Mud on windshield" or "mud on window." (18)

7. Unusual performance, occurrence or failures. M60A1: Steering loose (1), steering pull to the right. (1) M113: Lateral(s) out of adjustment. (2)

HIMAG: Gas pedal position, wrong angle, foot slides off. (7) Windshield cleaning system could not clean away mud, field of view partially obscured (6). Lost power, felt drag (5). Bouncing, bump, springy ride. (5)

12. Feel of ride. M60A1: "Average" or "OK" (6); "Fairly smooth" to "very good." (7) M113: "Average" to "very comfortable," "pretty good." (9)

HIMAG: "Smooth," "quiet," "good ride," "comfortable," "outstanding," "much better than in M60." (32) Shock absorption - "rough at high speeds," "very rough over rough terrain." (6)

21. Explanation of difficulties in operation. M60A1: "hard getting speed up hills." (2) Steering "slack, vehicle darted." (1) "Difficulty (steering) increased as speed increased." (1) M113: "not enough power, too many hills." (6) "Track drifts to right," "pulls to right." (3)

HIMAG: Braking - "too sensitive." (3) "Need more time to adjust to brakes." (1) Maintaining steady speed - "loss of power." (3) "Loss of power and this caused a loss of control." (1) "Can't get up to speed." (1)

32. Explanation of difficulties in driver subtasks. M113: Lack of power - "on hills and top speed," "not enough power." (2) "Speedometer and other instruments reading necessitates taking eyes completely off road for a few seconds." (1)

HIMAG: "Brakes too sensitive; needed more training" (stopping). (7) Reading speedometer - "Did not read speedometer; needs to be relocated." (6) Neutral steer turn - "Would not steer," "loss of power," "more training needed." (5) Ditch crossing - "Bottomed out," "slid sideways," "stuck in ditch," "needed more power." (5) Starting - "needed more training" (3, all three on first trial of the day).